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Certificate Series 5 (iii)
ICSE BIOLOGY

A TEXTBOOK OF ICSE BIOLOGY

For Class IX

by

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1
Cell Structure

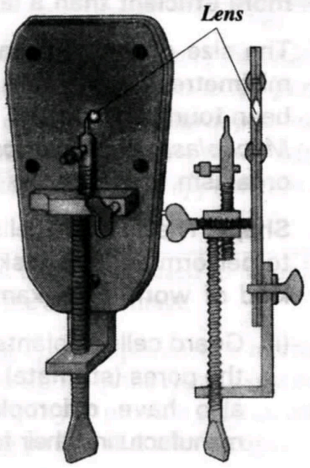
Introduction

The cell occupies the same central position in biology as the atom in the physical sciences. It is the basic unit of organisation or structure of all living matter. Being of microscopic dimensions (very tiny), the cell came under the study of scientists only in the 17th century, with the invention of the microscope. A **microscope** is an instrument used to magnify objects, i.e., increase the size of image.

Leonardo da Vinci (1452-1519), an Italian painter, used convex lenses to magnify objects upto ten times. Later, many lenses were combined together to form compound microscopes, having magnification power ranging from 300 to 1500 times. These microscopes used light (generally sunlight) to illuminate the object. Hence, these came to be known as **light microscopes.**

A.V Leewenhoeck (1632-1723)

A. V. Leeuwenhoeck (1632-1723) a Dutch cloth merchant, was among the first to construct a microscope. He discovered the minute forms of life such as bacteria and single-celled animals like *Infusoria* in a drop of water. The modern microscope uses a beam of electrons to scan the object and can magnify upto 2,00,000 times.



Front view Side view

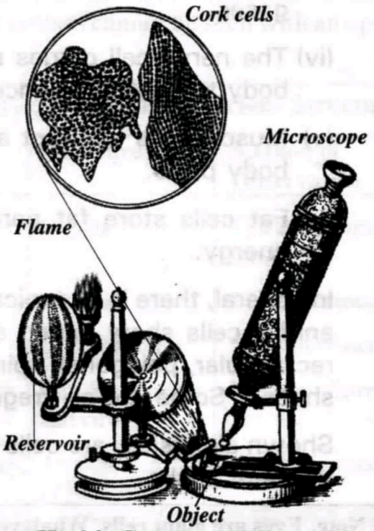
Leewenhock's Simple Microscope

Discovery of the Cell

The word cell is derived from the Latin word *"cellula"* which means "a little room". It was British botanist **Robert Hooke**, who in 1665, while examining a slice of bottle cork under his crude microscope observed its honey-combed or porous structure. He found it resembling the box-like living quarters or cells of the monks in a monastery and called the units, **cells. Jan Swammerdam** in 1658 gave the first description of the cell in his account of the red blood cells of the frog.

The Cell Theory

All living beings, whether plant or animal, start their life with a single cell. If they continue to be in this state, they are said to be **unicellular** e.g., yeast, bacteria, chlamydomonas, amoeba. If the cell divides and gives rise to organisms with more than one cell, the organism is termed as **multicellular.** Each cell is capable of carrying out the various metabolic life processes such as assimilation, respiration, reproduction, excretion, etc., that are essential for the survival of the organism.



Hook's Compound Microscope

In 1838, **Matthias Schleiden,** a German botanist, first proposed the idea that all **plants** consist of cells. A year later, **Theodor Schwann,** a German zoologist, independently asserted that all plants and **animals** are made up of cells, thus extending the theory to animal life. This joint finding forms the basis of the **cell theory.** Schwann believed that cells could be 'grown' or generated in a manner similar to crystals which 'grow' by depositing new material. However, research showed that during growth cells duplicate themselves through a process that came to be known as **"cell-division".**

In 1885, **Rudolf Virchow** aptly summarized these observations in the Latin phrase, *"Omnis cellulae cellua"*, (cells arise from pre-existing cells). As he explained, ***"where a cell exists, there must have been a pre-existing cell, just as the animal arises only from an animal and the plant only from a plant".*** Thus, a significant addition was made to the cell theory.

Cell: Shape and Size

A cell is a mass of protoplasm having a distinct nucleus and limited by a plasma membrane.

A cell is the smallest living unit which is able to carry out all the basic functions of life: growth, metabolism and reproduction. Some simple organisms (e.g., amoeba) consist of a single cell, while most plants and animals consist of many cells adapted to perform a particular function. But even in these multicellular organisms, the individual cells are capable of growing, feeding and reproducing.

1. **Size** of a particular cell is dependent on the **surface area/ volume** relationship.

   A small body possesses a relatively large surface area, and vice versa. Since many nutrients enter the cell and wastes leave the cell by diffusion, and the rate of diffusion is directly proportional to the area available, **a small cell is more efficient than a larger one.**

   The size of the cell ranges from 1/10th to 1/1000th of a millimetre. Certain cells, like the nerve cell in elephant, has been found to measure 1 m. The smallest cells are those of *Mycoplasma gallisepticum,* (1/10,000th of a millimetre) an organism intermediate between viruses and bacteria.

2. **Shape:** The different cells in plants and animals are specialised to perform definite tasks. A particular cell can do only one kind of work. For example:

   (i) Guard cells in plants control the opening and closing of the pores (stomata) that allow gaseous exchange. They also have **chloroplasts** to harness solar energy for manufacturing their food by the process of photosynthesis.

   (ii) Sieve cells in plants transport nutrients in plants.

   (iii) The red blood cells in animals transport respiratory gases.

   (iv) The nerve cell carries messages from one part of the body to another. Hence, they are very long.

   (v) Muscle cells contract and relax to allow movement of body parts.

   (vi) Fat cells store fat permanently, or until needed for energy.

   In general, there is no typical shape for cells. Both plant and animal cells show varied shapes such as spherical, oval, rectangular, polygonal, spindle-shaped, rod-shaped or star-shaped. Some are as irregular as the nerve cells.

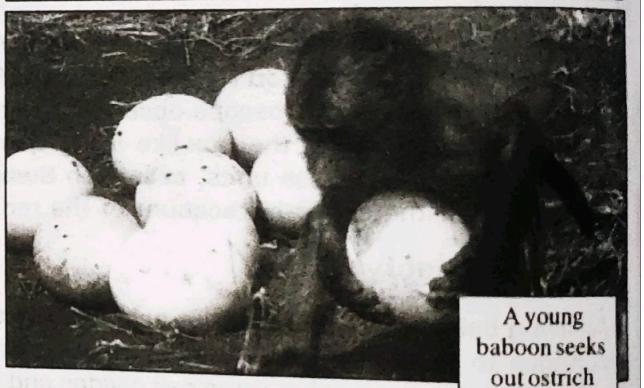
   Shown alongside, are cells of different shapes designed for different tasks.

Note: Eggs are giant cells. Whatever their size, they are just single cells.

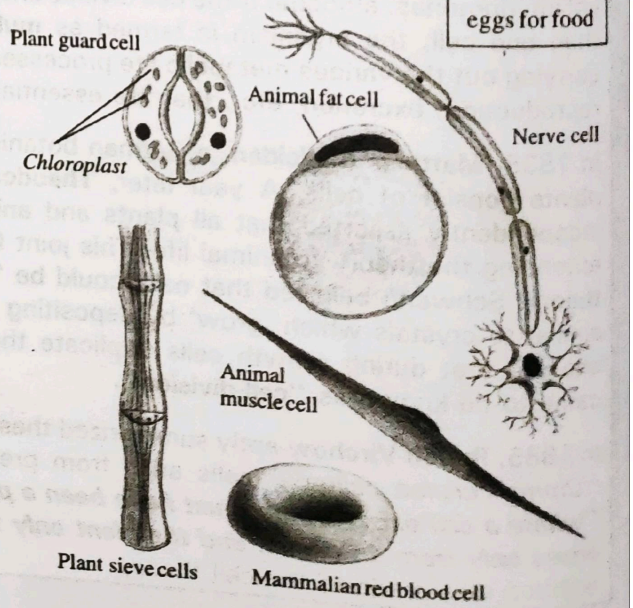
Points to Note

1. The single largest cell in the world is of an **ostrich.**
2. The smallest cells are those of the ***Mycoplasma.***
3. The largest human cell is the **female ovum** (0.01 mm in diameter).
4. The smallest human cell is the **red blood cell** (0.0075 mm or 7.5 µm).
5. In humans, the number of cells is estimated to be about 1000 trillion (10^{14}).
6. An average human cell measures between 0.01 mm to 0.03 mm.
7. Nerve cells in animals are the longest cells.

Cells generally remain small. A small size offers a larger surface area which facilitates exchange of respiratory gases, intake of nutrients, removal of wastes from the cell, by diffusion.



A young baboon seeks out ostrich eggs for food



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A. To observe an animal cell under a compound microscope.

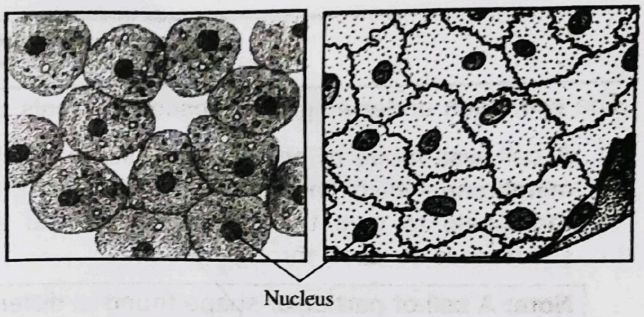
Procedure:

1. Run a finger round the inside of the cheek.
2. Smear the fluid thus collected on a clean dry slide.
3. Add a drop of methylene blue solution to the slide. (Staining is done to bring the nucleus into prominence.) Allow it to stand for a minute and then drain it away by tilting the slide.
4. Now observe the cell under the low power of a compound microscope.

B. To observe a plant cell under a compound microscope.

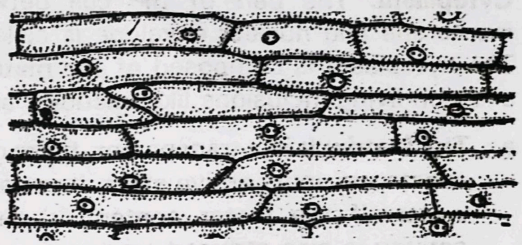
Procedure:

1. Strip the epidermis from the inside of an onion scale.
2. Place a piece of the tissue on a glass slide and add a few drops of water.
3. A drop of dilute iodine solution may be added to stain the nuclei light brown or highlight starch grains if present. (Starch turns blue-black in iodine).
4. Now observe the cell under the low power of a compound microscope. The skin is one cell thick, hence, the transparent cells can be seen easily.



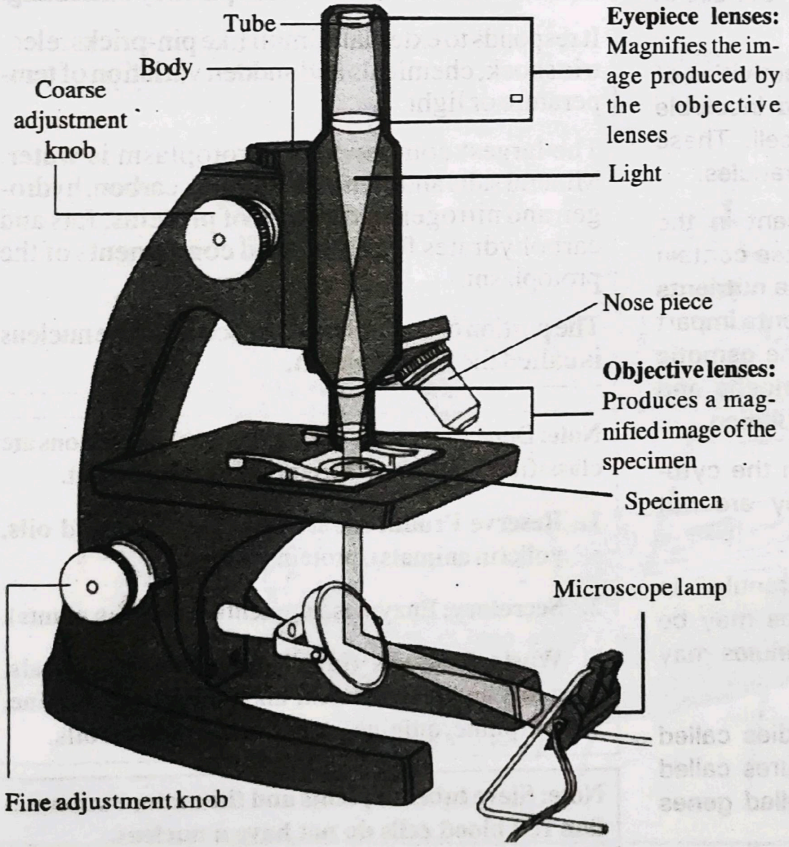
*The inner lining of the cheek is composed of a single layer of flat, **cuboidal epithelial** cells with centrally located nucleus.*

Epithelial cells from the body cavity of frog .



*Parenchyma cells make up the skin of the **onion**. The nucleus and cytoplasm are pushed to the periphery while the vacuole occupies the central position. The shape is determined by the pressure of the adjoining cells. If isolated, the cells would appear rounded or oval.*

Path of Light in a Light Microscope



A microscope is an instrument used to magnify objects. i.e., increase the size of image.

In addition to magnifying a specimen, a microscope must produce a clear image of the closely spaced parts of the object. The ability to provide such an image is called the **resolving power of a microscope.**

The best optical microscopes cannot resolve parts of objects that are closer than about 0.0002 of a millimetre. Anything smaller in the specimen such as atoms, molecules and viruses cannot be seen with an optical microscope.

Microscope used for Study of various Structures

Field	Structure	Method of Observation
Anatomy	Organs	Eye and simple lenses
Histology	Tissues	Light microscope
Cytology	Cells, bacteria	X-ray microscopy
Ultra microscopic morphology	Cell components and viruses	Electron microscope
Molecular biology, atomic structure	Arrangement of atoms	X-ray microscopy

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Cell Structure

The cell, seen under a light microscope reveals the following:

1. A **cell wall** made of cellulose (in plants only) and **plasma membrane** which encloses the protoplasm. These structures help to give the cell its shape and allow various substances to pass through them.

> **Note:** A cell of particular shape found in different parts of the plant or animal body is according to the role or function it has to perform as part of the tissue or organ system. The shape of the cell may also vary due to internal or mechanical stress or pressure.

2. **Cytoplasm:** The part of the cell between the plasma membrane and nuclear envelope is called the **cytoplasm.** The cytoplasm is composed of the **matrix**, the **organelles** and non-living inclusions like **vacuoles** and **granules.**

   a. **The Matrix:** It is a transparent, homogeneous semi-fluid substance. In its active state, it remains saturated with water. If the water content is decreased, its vital activity is also reduced, and may even halt, as in the case of dry seeds. Living cytoplasm is always in a state of movement.

   b. **The Organelles:** Organelles are living parts of the cell having definite shape, structure and function. These tiny chemical factories produce hormones, enzymes and other substances which are released for the use in the cell and elsewhere in the body.

   c. **Inclusions:** As a result of diverse metabolic activities of the cell organelles, a variety of soluble and insoluble chemical products accumulate within the cell. These are generally found stored in vacuoles or granules.

      (i) **Vacuoles:** These are clear spaces present in the cytoplasm enclosed by a membrane. These contain fluid called **cell sap** in which water soluble **nutrients** and **pigments** are found. Dissolved pigments impart colour. Vacuoles also help to maintain the **osmotic pressure** in a cell. In protozoans like amoeba and paramoecium vacuoles help in **osmoregulation.**

      (ii) **Granules:** These are tiny bodies found in the cytoplasm of plants and animal cells. They are not bounded by membrane.

      Sometimes **pigments** may occur as granules in special cells, **glycogen** or **starch** granules may be present as reserve food, or **secretory** granules may accumulate in gland cells.

3. **Nucleus:** It contains one or more dense bodies called **nucleoli** and a network of thread-like structures called **chromatin.** It bears hereditary characters called **genes** and **regulates metabolic activities of the cell.**

Living parts of a Cell

1. **Cell membrane**
2. **Cytoplasm:**
   a. **Endoplasmic Reticulum**
   b. **Mitochondria**
   c. **Golgi Complex**
   d. **Ribosomes**
   e. **Lysosomes**
   f. **Centrosome (animals only)**
   g. **Plastids (plants only)**
3. **Nucleus:**
   a. **Nuclear membrane**
   b. **Nucleoli**
   c. **Nucleoplasm**
   d. **Chromatin fibres**

Non-living parts of a Cell

1. Cell wall (plants only) Cellulose is a fibrous polysaccharide
2. Granules
3. Vacuoles
4. Fat droplets

Protoplasm

The protoplasm is a transparent semi-fluid granular substance that loses its transparency on heating.

It responds to external stimuli like pin-pricks, electric shock, chemicals and sudden variation of temperature or light.

The largest component of protoplasm is water. Mineral salts and elements oxygen, carbon, hydrogen and nitrogen in the form of proteins, fats and carbohydrates form the solid components of the protoplasm.

The portion of protoplasm that occurs in the nucleus is called the **nucleoplasm.**

Note: Depending upon their nature, cell inclusions are classified as reserve, secretory or waste product.

1. **Reserve Product:** Carbohydrates, fats and oils, yolk (in animals), proteins.
2. **Secretory:** Enzymes, pigments, nectar (in plants).
3. **Waste Products (in plants):** Mineral crystals, gums and resins, latex, alkaloids (e.g., nicotine, morphine, quinine), tannin and essential oils.

Note: Sieve tubes in plants and the mature mammalian red blood cells do not have a nucleus.

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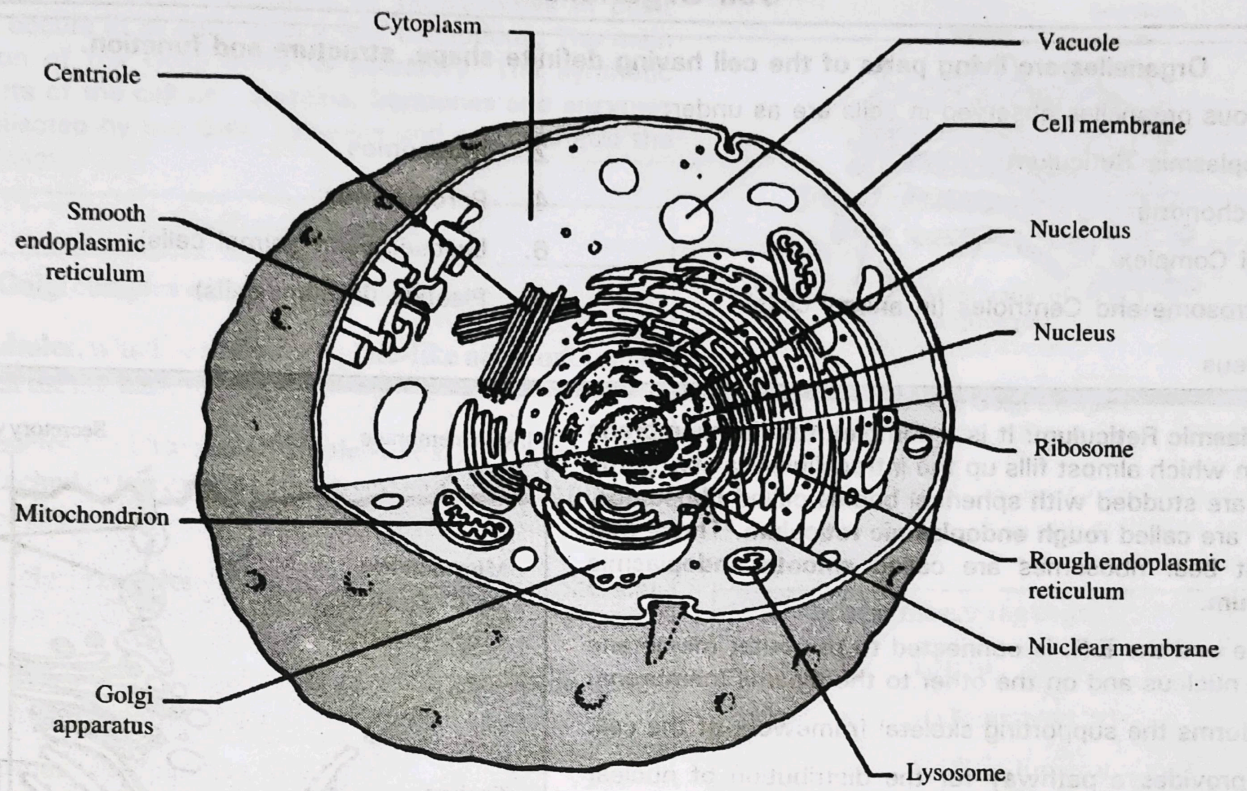
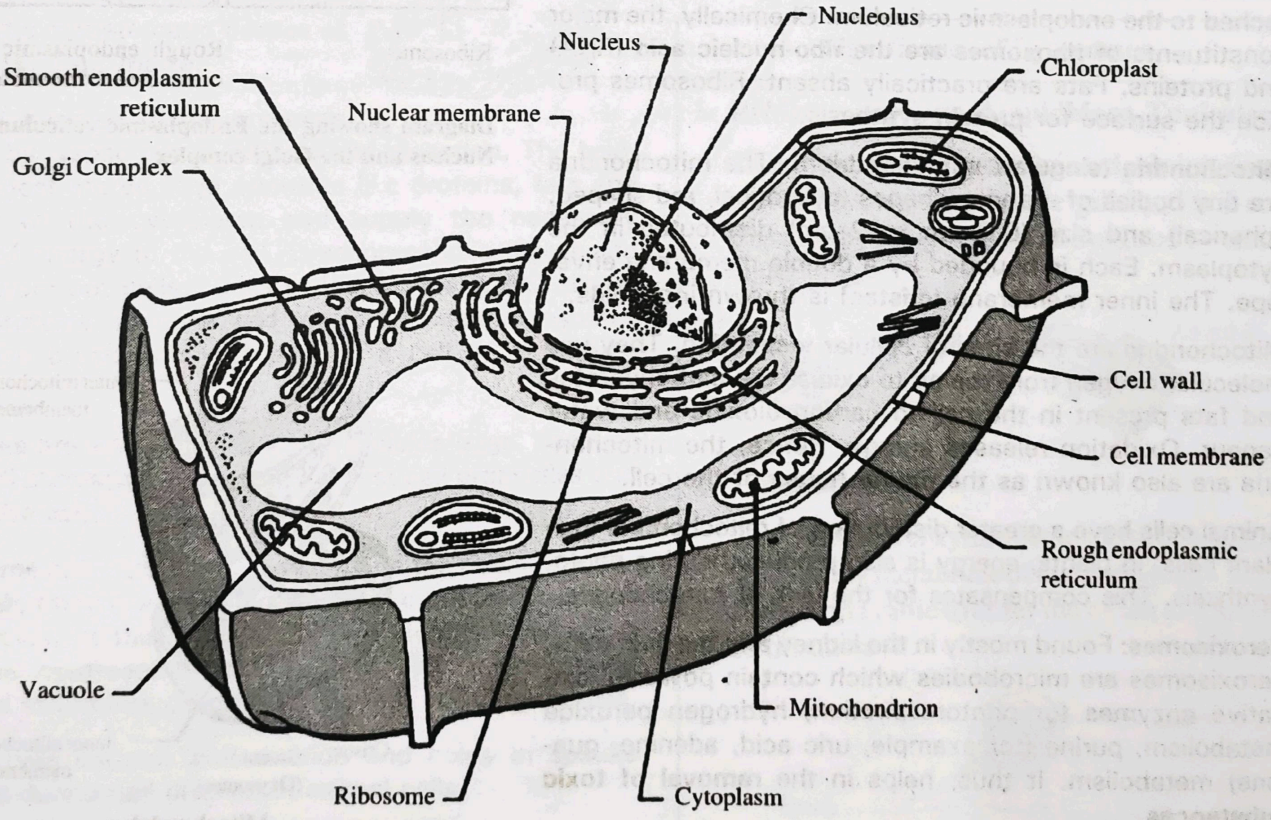
A Typical Animal Cell



A Typical Plant Cell



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Cell Organelles

Organelles are living parts of the cell having definite shape, structure and function.

The various organelles observed in cells are as under:

1. Endoplasmic Reticulum
2. Ribosomes
3. Mitochondria
4. Peroxisomes
5. Golgi Complex
6. Lysosomes(in animal cells)
7. Centrosome and Centrioles (in animal cells)
8. Plastids (in plant cells)
9. Nucleus

1. **Endoplasmic Reticulum:** It is a complex **tubular membrane** system which almost fills up the intracellular cavity. Some tubes are studded with spherical bodies called **ribosomes.** These are called **rough endoplasmic reticulum.** Those that do not bear ribosomes are called **smooth endoplasmic reticulum.**

   On one end the E.R. is connected to the outer membrane of the nucleus and on the other to the plasma membrane.

   (i) It forms the supporting skeletal framework of the cell.

   (ii) It provides a pathway for the distribution of nuclear material from one cell to the other.

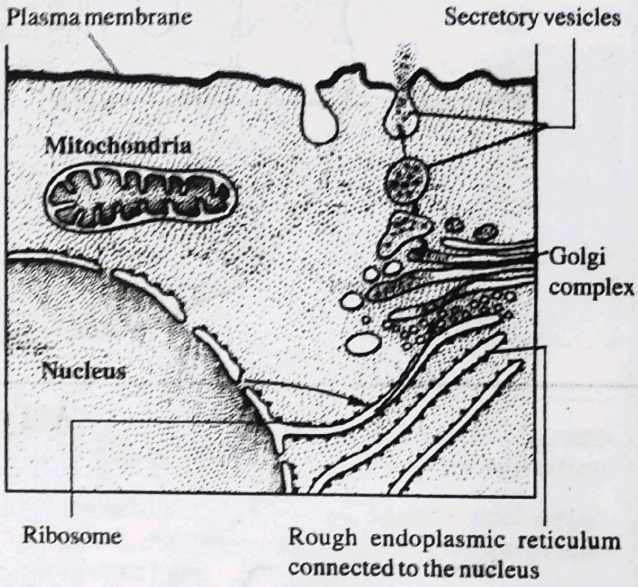


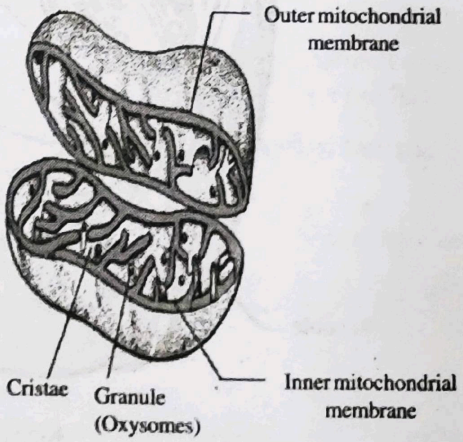
Diagram showing the Endoplasmic reticulum with the Nucleus and the Golgi complex

2. **Ribosomes:** Ribosomes are dense, spherical and granular particles which occur freely in the matrix or remain attached to the endoplasmic reticulum. Chemically, the major constituents of ribosomes are the **ribo-nucleic acid** (RNA) and proteins. Fats are practically absent. Ribosomes provide the surface for **protein synthesis.**

3. **Mitochondria (singular: mitochondrion):** The mitochondria are tiny bodies of varying shapes (cylindrical, rod-shaped, spherical) and size (0.2 μm to 2 μm) distributed in the cytoplasm. Each is bounded by a double membrane envelope. The inner membrane (**cristae**) is thrown into folds.

   Mitochondria are the sites of **cellular respiration.** They use molecular oxygen from the air to oxidise the carbohydrates and fats present in the cell to carbon dioxide and water vapour. Oxidation releases energy. Hence, the mitochondria are also known as the **power house** of the cell.

   Animal cells have a greater distribution of mitochondria than plant cells. In plants, energy is also produced during photosynthesis. This compensates for the lack of mitochondria.



Mitochondrion

4. **Peroxisomes:** Found mostly in the kidney and the liver cells, peroxisomes are microbodies which contain powerful oxidative enzymes for photorespiration, hydrogen peroxide metabolism, purine (for example, uric acid, adenine, guanine) metabolism. It thus, helps in the **removal of toxic substances.**

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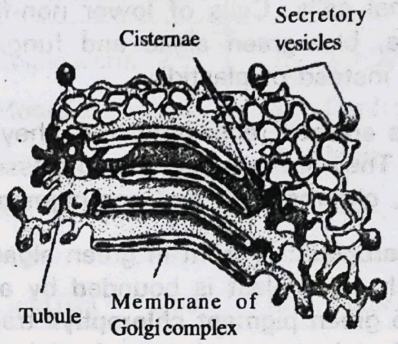
5. **Golgi Complex:** The Golgi Complex, also named Golgi Bodies or the Golgi Apparatus (or **dictyosomes** in plant cells), occurs in all cells with a few exceptions. The main function of the Golgi Body, is **secretory**. The synthetic products of the cell i.e., **proteins, hormones and enzymes** are collected by the Golgi vacuoles and secreted into the cytoplasm.



The Golgi Complex

The Golgi Complex

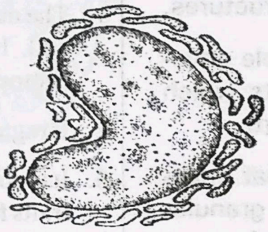
Each Golgi complex consists of the following:

1. **Tubules**, which are flattened plate-like net-work found near the nucleus.
2. **Vesicles**, which are small droplet-like sacs. These remain attached to the tubule at the distal end, near the plasma membrane.
3. **Golgian vacuoles**, which are large, spacious spherical structures.

Note: The Golgi complex is absent in bacteria, blue-green algae, mature sperms and red blood cells of animals.

Scale used for measuring cells:		
1 cm	=	10 mm
1 mm	=	1000 microns (μ)
1 m	=	1000 millimicrons (mμ)

6. **Lysosomes:** Lysosomes are tiny spherical sac-like structures evenly distributed in the cytoplasm. Occurring mostly in animal cells, irregular-shaped lysosomes have been located in the meristematic tissues of plant roots, e.g., maize.



The chief function of the enzymes secreted by lysosomes is **intracellular digestion**. The lysosomes digest stored food contents like proteins, fats and glycogen of the cytoplasm and supply the necessary amount of energy to the cell. Lysosomes also digest and remove worn out cells. Cells of leucocytes (WBC) digest foreign proteins, bacteria and viruses. Hence, lysosomes control the break down of part of a cell or of foreign particles.

Lysosomes are also referred to as **'suicide bags'** because during cell starvation they slowly digest cell organelles and destroy the cell.

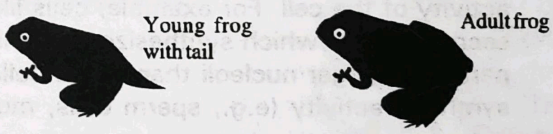
7. **Centrosome and Centrioles:** Just outside the nucleus of the **animal cell**, there is a small clear area of cytoplasm without any granules. In this portion of the cytoplasm, which is called the **centrosome**, one or two tiny micro-tubular cylindrical structures develop. These are called **centrioles**.

The **centriole** initiates cell division and helps in **spindle formation** during cell division in animal cells.

Significance of Lysosomes

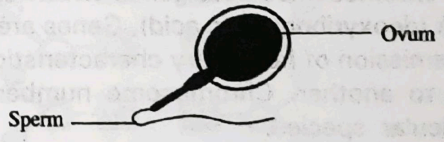
1. In Metamorphosis (Amphibians, Tunicates)

During the transformation of a tadpole into frog, the embryonic tissues like gills and tail are digested by the lysosome and utilised by other cells.



2. In Fertilisation

The lysosomal enzymes of the sperm cells digest the limiting membrane of the ovum (egg). Thus the sperm is able to enter the ovum and affect fertilisation.



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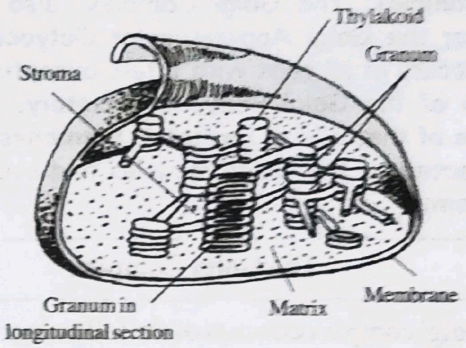
8. **Plastids**: Plastids occur in most plant cells and are absent in animal cells. Cells of lower non-flowering plants like bacteria, blue-green algae and fungi contain **chromatophores** instead of plastids.

Plastids are self replicating, i.e., they have the power to divide. They are grouped in two classes: **Pigmented** (chloroplast, chromoplast) and **non-pigmented** (leucoplast).

a. **Chloroplast:** Present in green algae and higher plants, each chloroplast is bounded by a double membrane. The green pigment **chlorophyll** traps solar energy and utilises it to manufacture food for the plant.

b. **Chromoplast:** The variously pigmented plastids by imparting colour to flowers, attract insects for pollination.

c. **Leucoplast:** These are colourless, rod-shaped or spheroid pigments which store food in the form of carbohydrates (starch), lipids and proteins. They are found in seeds, meristematic cells, sex-cells, ground tissue of certain roots and stems.



Chloroplast

Example of Chromoplast

(i) **Carotenoids (insoluble in water):** Imparts yellow and orange colours. It is contained in carrots.

(ii) **Anthocyanins (soluble):** Imparts red and blue colours. It is contained in beetroot.

9. **Nucleus**

The nucleus has been described as the **brain of the cell** as it regulates all metabolic and hereditary activities of the cell. The nucleus is composed of the following structures.

a. **Nuclear Membrane:** It is a selectively permeable envelope-like structure around the nuclear contents which separates the nucleoplasm from the cytoplasm.

b. **The Nucleoplasm:** The space within the nuclear envelope is filled by a transparent semi-solid, granular ground substance or matrix called the **nucleoplasm.**

The nuclear components such as the **nucleolus** and **chromatin threads** remain suspended in it.

c. **The Nucleolus:** It is a dense spherical granule contained within the nucleus. Its size is related to the synthetic activity of the cell. For example, cells like neurons and secretory cells which synthesize proteins, have a comparatively larger nucleoli than those cells that have no synthetic activity (e.g., sperm cells, muscle cells).

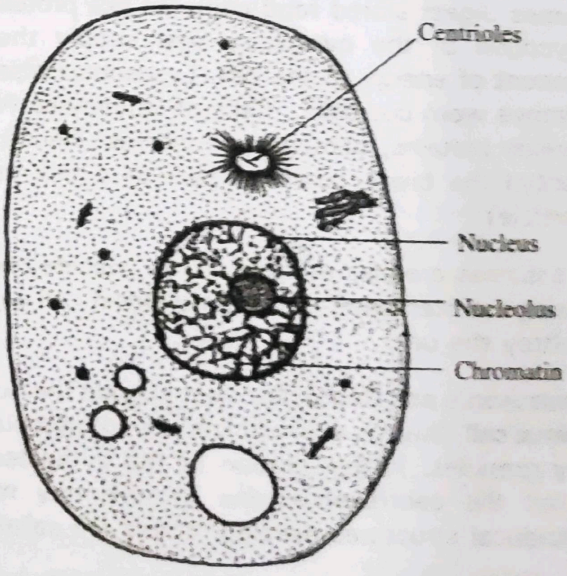
Role of Nucleus

1. The nucleus controls all metabolic activities of the cell. If the nucleus is removed from a cell, the protoplasm eventually dries up and dies.
2. It regulates cell division.
3. It is concerned with the transmission of hereditary traits from parent to offspring.
4. The nucleolus stores proteins.

Chromatin fibres

These are very fine thread-like coiled filaments uniformly distributed in the nucleoplasm. At the time of cell division, the chromatin becomes thick and ribbon-like and are known as **chromosomes**.

The chromosomes bear genes which are composed of the DNA (deoxyribonucleic acid). Genes are responsible for the transmission of hereditary characteristics from one generation to another. Chromosome number is constant for a particular species.



Animal Cell showing the Centrioles contained in the Centrosome, Nucleus, Nucleolus and Chromatin fibres

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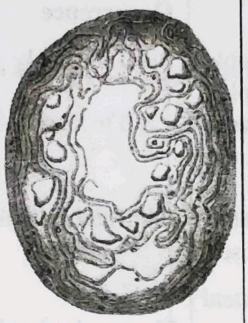
Prokaryotic and Eukaryotic Cells

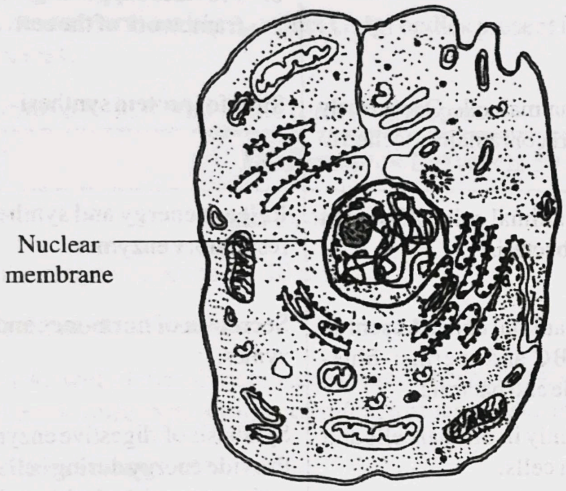
Prokaryotic cell



In lower organisms like the bacteria and blue-green algae, the nuclear membrane is absent. As such, the nuclear material is in direct contact with the cytoplasm. Such cells are called prokaryotic cells.

Eukaryotic cells

In eukaryotic cells, the nuclear material is enclosed or bounded by a membrane. Higher organisms have eucaryotic cells.



Chromosome Number of some Organisms

1.	Round worm	2	7.	Sunflower	34
2.	Mosquito	6	8.	Garden pea	14
3.	Frog	26	9.	Maize	20
4.	Rat	42	10.	Rice	24
5.	Man	46	11.	Onion	16
6.	Gold fish	100	12.	Guinea pig	64

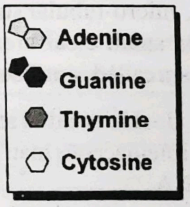
Genes

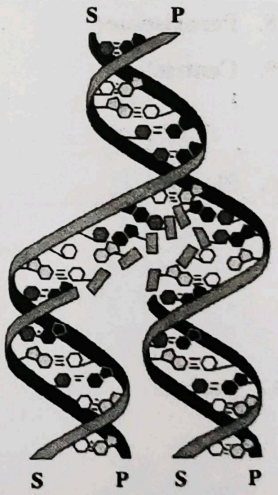
Genes are segments of **DNA.**

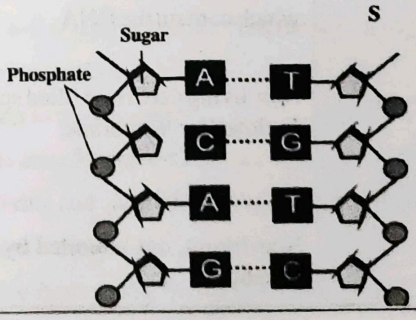
A gene is the functional unit of chromosome arranged in single, linear order along the chromosome. One gene may be responsible for one or several cell functions or a single function may be carried out by a set of genes.

Points to Note

1. DNA or deoxyribonucleic acid is a **helically-twisted double chain** poly-deoxyribonucleotide macromolecule.
2. Each spiral of the DNA molecule has 10 nucleotides. The distance between two nucleotides is 3.4Å. The diameter of a DNA molecule is 20Å and its radius is 10Å.
3. Two types of nitrogenous bases occur in DNA
   (i) **Purines:** adenine (A) ; guanine (G)
   (ii) **Pyrimidines:** cytosine (C) ; thymine (T)
4. The two DNA chains are **antiparallel** to each other and are held together by hydrogen bonds between their bases.
5. The total molar amount of purines and pyrimidines in any specimen of DNA is always equal, i.e., **A + G = T + C.**
   A = T and G = C, therefore, the ratio **A/T =1 and G/C = 1**
6. Base ratio (A + T) / (G + C) may vary from one species to another, but is constant for a given species. This ratio, called **dissymmetry ratio** can be used to identify the source of DNA and help in the classification of organisms.







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Ready Reckoner

Part of Cell	Nature	Occurrence	Function
1. Cell Wall	Non-living, semi-rigid, permeable membrane, composed of complex polysaccharide called cellulose.	Plant cells only	a. Gives strength and rigidity to the cell. b. Allows free passage of substances through it.
2. Cell Membrane	Living, differentially permeable two-layered membrane, composed of fats and proteins.	Plant and animal cells.	Regulates entry and exit of substances in and out of the cell.
3. Endoplasmic-reticulum	Living, network of tubular membrane. Connected at one end to the nucleus and on the other to the plasma membrane. May be smooth or rough.	Plant and animal cells. Absent in RBC's and embryonic cells.	a. Provides a pathway for distribution of nuclear material. b. Provides supporting skeletal framework of the cell.
4. Ribosomes	Living, single walled dense, spherical bodies composed mainly of RNA.	Plant and animal cells. Occur freely in the matrix or remain attached to ER.	Sites for protein synthesis.
5. Mitochondria	Living, various shapes, double-walled, inner wall thrown into folds called **cristae.** DNA present.	Plant and animal cells. Absent in RBC and bacteria.	Release energy and synthesize respiratory enzymes.
6. Golgi Complex	Living, consists of tubules, vesicles and vacuoles.	Plant and animal cells. Absent in mature RBC and sperms; blue-green algae and bacteria.	Secretion of hormones and enzymes.
7. Lysosomes	Living, sac-like vesicles with proteinaceous matrix.	Found mainly in animal cells and some plant cells.	Synthesis of digestive enzymes. Provide energy during cell starvation. Associated with ageing
8. Peroxisomes	Living, membrane-bound sac.	Kidney and liver cells.	Removal of toxic substances.
9. Centrioles	Living, micro-tubular structures found in small clear area of the cytoplasm called **centrosome.**	Animal cells only. Lies just outside the nucleus.	Initiates cell division.
10. Plastids	Living, double-walled structure with a proteinaceous matrix. Contains DNA.	Plant cells only.	a. **Chloroplast:** Site of photosynthesis. b. **Chromoplast:** Impart colour to flowers and fruits. c. **Leucoplast:** Store starch, lipids and proteins.
11. Nucleus	Living, contains dense bodies called nucleoli and a network of thread-like structures called chromatin which contain the DNA.	Plant and animal cells. Absent in mature mammalian red blood cells and sieve tubes in the phloem tissue of vascular plants.	a. Regulates growth and reproduction of cells. b. Chromosomes are bearers of hereditary characteristics. c. Nucleolus stores proteins.
12. Vacuoles	Non-living part, fluid filled spaces enclosed by membrane.	Generally in plant cells. If present in animal cells, small and temporary.	a. Store excess water, minerals, food substances pigments and waste products. b. Gives turgidity to the cell.
13. Granules	Non-living, not bounded by any membrane.	Plant and animal cells. Remains suspended in the cytoplasm.	Store fats, proteins and carbohydrates.

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Major differences between Animal Cell and Plant Cell

Animal Cell	Plant Cell
1. Cell wall absent. Cellulose in any form is also absent.	Cellulose cell wall is present in plant cells.
2. Cytoplasm is denser, more granular and occupies most of the space in the cell.	Cytoplasm is pushed to the periphery and forms a thin lining against the cell wall.
3. Vacuoles absent. If present, they are small, temporary and concerned with excretion or secretion.	Vacuoles are large and prominent. Maybe one or more.
4. Plastids are absent.	Plastids are generally present.
5. Centrosome is present with one or two centrioles.	Centrosome is absent but two small clear areas called polar caps are present. These participate in cell division.
6. Prominent and highly complex Golgi bodies present near the nucleus.	Several subunits of Golgi apparatus called dictyosomes present.
7. Reserve food stored in the form of **glycogen.**	Reserve food stored in the form of **starch.**

Differences between Prokaryotic Cells and Eukaryotic Cells

Prokaryotic Cell	Eukaryotic Cell
1. Size ranges between 1 - 10 μm.	Size ranges between 5 - 100 μm.
2. Lacks nuclear membrane.	Nuclear membrane present.
3. Lacks well defined membrane bound organelles like endoplasmic reticulum, Golgi complex, mitochondria, etc.	Organelles like endoplasmic reticulum, Golgi complex, mitochondria, etc., are present.
4. Single chromosome.	More than one chromosome present.
5. Tissue formation absent.	Tissue formation present in many groups.
6. Cell division by binary fission or budding.	Cell division is mitotic or meiotic.
Example: Bacteria, Blue-Green algae.	**Example:** Plants ranging from algae to angiosperms. Animals ranging from protozoa to mammals.

Important Inventions and Discoveries

Scientist	Year	Invention /Discovery
1. **Jenssen and Hans**	1658	Gave the first description of cell.
2. **Robert Hooke**	1665	Named the cell.
3. **A. V. Leeuwenhock**	1673	Simple Microscope
4. **Robert Brown**	1828	a. Reported Brownian movement in cells.
	1836	b. Described the nucleus as a central feature of plant.
5. **M. J. Schleiden**	1838	Described the nucleoli and proposed the **"cell theory"** along with T. Schwann.
6. **T. Schwann**	1839	Applied cell theory to animals.
7. **J. E. Purkinje**	1840	Named cell contents as protoplasm.
8. **R. Virchow**	1855	Stated that all cells arise from pre-existing cells.
9. **Schultze**	1861	Identified cell as living and called the protoplasm **"physical basis of life".**
10. **M. Knoll and E. Ruska**	1932	Invented the electron-microscope.
11. **J. D. Watson and F. H. C. Crick**	1953	Proposed the double-helix model for the DNA molecule.

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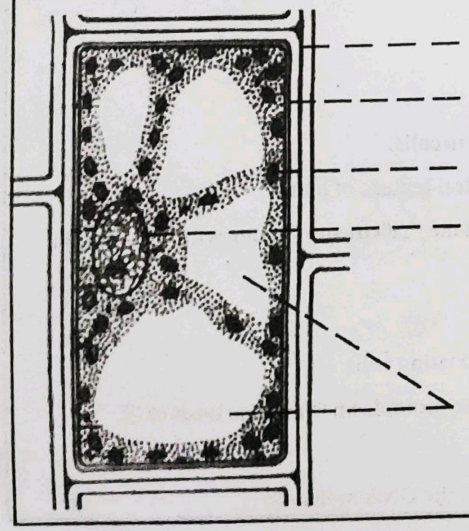
Exercise

1. Define a cell.
2. **Give one distinguishing feature between the following:**
   a. Cell wall and Cell membrane
   b. Cytoplasm and Nucleoplasm
   c. Chromoplast and Leucoplast
   d. Cell organelle and Cell inclusion
   e. Chloroplast and Chromoplast
   f. Centrosome and Centrioles
   g. Vacuoles and Granules
   h. Smooth and Rough Endoplasmic Reticulum
   i. Chloroplast and Chlorophyll
   j. Prokaryotic cell and Eukaryotic cell
3. **Explain briefly:**
   (i) Mitochondria are also called the "power house" of the cell.
   (ii) The nucleus is often referred to as the "brain" of the cell.
   (iii) Lysosomes are also called "suicide bags".
   (iv) A small cell is more efficient than a large cell.
4. State three differences between a plant cell and an animal cell.
5. **Fill in the blanks with organelle-function associations.**
   (i) Ribosomes and _____.
   (ii) Nucleus and _____.
   (iii) _____ and respiratory enzymes.
   (iv) Endosplasmic reticulum and _____.
   (v) _____ and digestive enzymes.
   (vi) _____ and hormones, enzymes.
6. **Give two examples of each of the following types of cell inclusions:**
   (i) Reserve products (ii) Secretory products (iii) Waste products in plant cells
7. **Name two organisms in which the following srtuctures are absent:**
   (i) Nucleus (ii) Golgi complex
8. **Label the parts indicated by guidelines and answer the questions given below:**



1. _____
2. _____
3. _____
4. _____
5. _____

(i) Is the given diagram that of a plant cell or an animal cell?

(ii) Mention three evidences visible in the diagram to support the answer given in (i).

(iii) Mention any two functions of the part labelled (4).

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2
Tissue and Tissue System

Introduction

Every organism, whether its body consists of a single cell (unicellular) or a mass of cells (multicellular), can perform all vital life activities. It can respire, feed, excrete and reproduce.

1. **Tissue:** In multicellular organisms, the increase in body size makes it difficult for each cell to efficiently cope with the vast physiological requirements of the organism. Therefore, the cells, although potentially capable of performing all essential activities are assigned special functions.

   * As cells grow, they acquire specific shapes and characteristics to enable them to perform definite functions i.e., the cells get differentiated.
   * Generally cells of the same shape and characteristics grow together and combine into a group for carrying out a common function.
   * Each group of such cells give rise to **'a tissue'**.

   A tissue is defined as a group of cells of the same type or of the mixed type, having a common origin and performing an identical function.

2. **Tissue System:** Several tissues, which may be structurally similar or different, may collectively perform the same function. The grouping of specialised cells forms tissues and the division of labour resulting from the grouping of cells gives rise to the **tissue-system**.

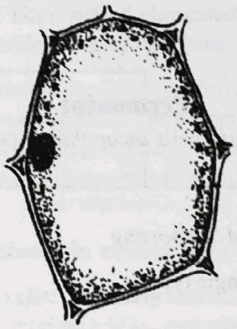
   A tissue system can be defined as a collection of tissues of common origin performing the same general function.

   Example: There are three systems recognised in the organisation of plant bodies:

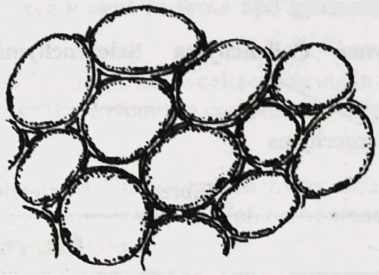
   a. The outermost layer of cells of any organ, root, stem or leaf is primarily protective in function. The **"Epidermal Tissue System"** makes up this layer.

   b. The **xylem** and **phloem** tissues in plants (roots, stems or leaves) conduct or transport water or food from one part to another. These form the **"Vascular Tissue System"**

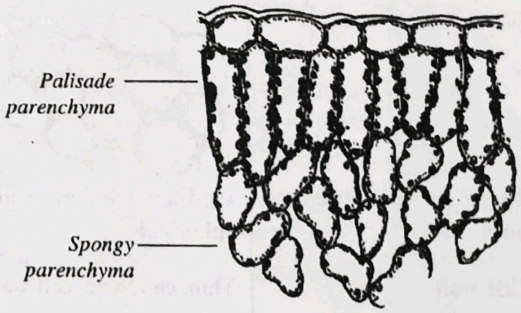
   c. **"The Ground or Fundamental Tissue System"** forms the main bulk of the plant body and extends below the epidermis to the centre (excluding the vascular bundles). Its primary functions are **manufacture** and **storage of food** material. It also has a **mechanical function.**



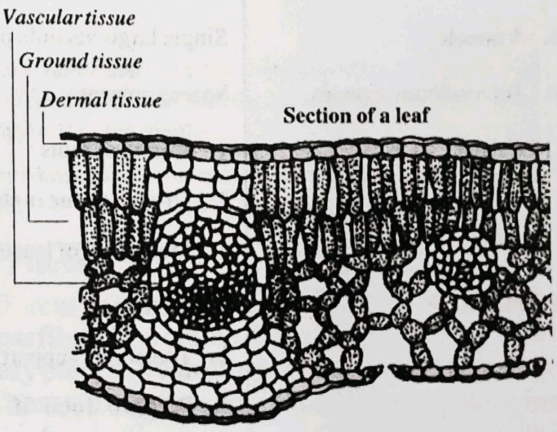
A typical living plant cell



A group of thin walled parenchyma cells



Parenchyma tissues in a leaf perform photosynthesis



Tissue Systems in a Plant

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Plant Tissues

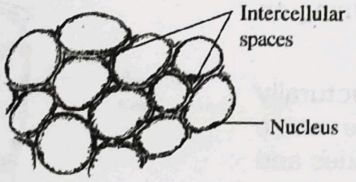
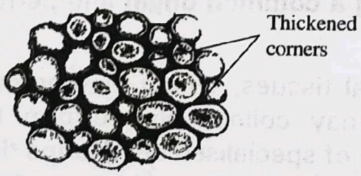
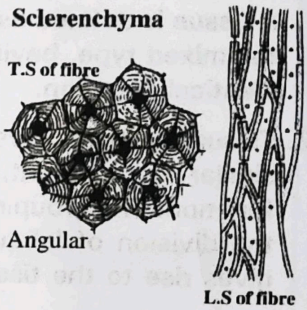
In plants, there are basically two types of tissues - Permanent Tissue and Meristematic Tissue. This differentiation is based on the ability of the mature cells of the tissue to divide and produce new cells.

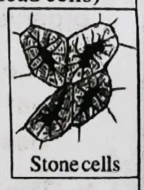
Classification of Plant Tissues

Plant Tissue

- **Permanent** *(Mature cells incapable of cell division)*
  - **Simple** - *Protective and Supporting* (Tissue composed of single type of cells)
    - **Parenchyma**
    - **Collenchyma**
    - **Sclerenchyma**
      - Fibres
      - Sclereids
    - Chlorenchyma
  - **Complex** - *Conducting* (Tissue composed of more than one cell)
    - **Phloem**
      1. Sieve tube
      2. Companion cell
    - **Xylem**
      1. Xylem vessels
      2. Tracheids
- **Meristematic** *(Cells are capable of cell division)*
  - **Apical** (Tips of root and stem)
  - **Lateral** (Below bark, Cambium in dicot roots and stems)
  - **Intercalary** (Internodes of stem)

Characteristics of Simple, Permanent Tissues

NATURE	Parenchyma	Collenchyma	Sclerenchyma
			
1. Shape (in transverse section)	Isodiametric, generally oval or spherical.	Elongated	Angular
2. Cell wall	Thin, cellulose cell wall.	Cell wall unevenly thickened with **cellulose** at corners.	Cell wall evenly thickened with **lignin.**
3. Nucleus	Nucleus present (living cells)	Nucleus present (living cells)	Nucleus absent (dead cells)
4. Vacuole	Single large vacuole present.	Vacuole small.	Vacuole absent
5. Intercellular spaces	Spaces present	Generally absent	Absent
OCCURRENCE	1. Cortex of roots 2. Ground tissue in stems 3. Mesophyll of leaves	1. Below epidermis in stems. 2. Generally absent in roots, leaves and monocot stems.	1. Stems 2. Veins of leaves 3. Hard covering of seeds, nuts
FUNCTION	1. Store food 2. Temporary support 3. Prepare food if chloroplast present.	1. Provide mechanical support. 2. Prepare food if chloroplast present (young dicot stems, or herbaceous plants).	Fibres provide **mechanical strength** and help in **conduction** when present in secondary xylem. Sclereids provide **protection.**


Stone cells

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Characteristics of Permanent Complex Tissues

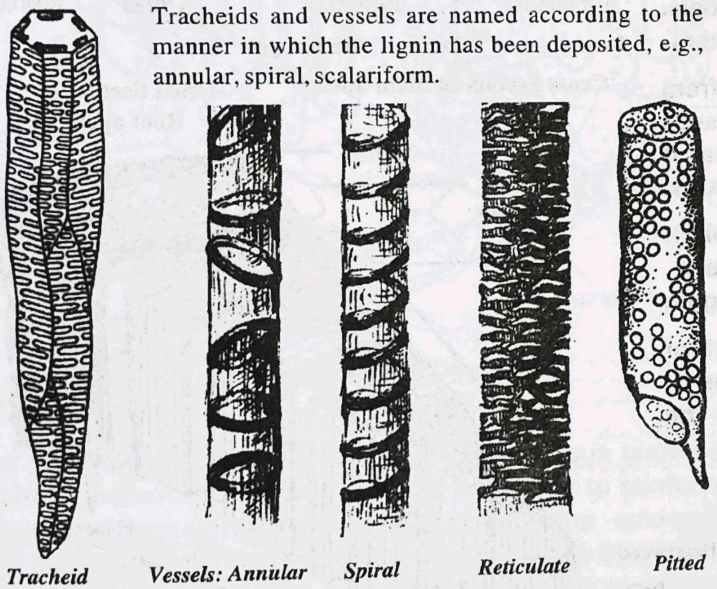
Xylem

Nature Consist mainly of dead elements - tracheids, vessels, xylem fibres and xylem parenchyma (living). Tracheids and vessels are the main elements of the xylem. They are conducting tissues. It may be noted that except the **xylem parenchyma**, all other elements at maturity consist of dead cells. The length of xylem fibres range from 20 mm to 550 mm.

a. **Tracheids:** Elongated cells with sloping walls enclosing a large empty cavity. The walls are heavily thickened with lignin.

b. **Vessels:** Cylindrical tube-like structures formed by a row of cells placed end to end. The transverse wall between the cells partly or almost completely dissolve to form a continuous channel or water-pipe. These also have lignified walls.

Tracheids and vessels are named according to the manner in which the lignin has been deposited, e.g., annular, spiral, scalariform.



Tracheid *Vessels: Annular* *Spiral* *Reticulate* *Pitted*

Xylem vessels

Occurrence In **root, stem** and **leaf** of the higher plants. They occur together with the phloem and form the **vascular bundle.**

Function

1. **Tracheids and vessels conduct water** and minerals upwards from the roots to the stem and leaves.
2. Older xylem tissue form the **wood** and do not take part in conduction. Their walls being lignified, they give **mechanical strength** to the plant.

Phloem

Consists of living elements - **sieve tubes, companion cells, phloem parenchyma and bast fibres.**

a. **Sieve tubes:** Thin-walled elongated cells placed end to end forming a slender tubular structure.

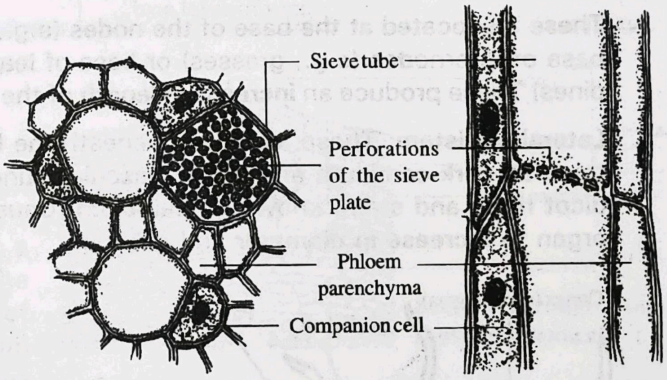
The transverse end walls are perforated by a number of pores likening it to a sieve plate. The cytoplasm of one sieve element is continuous with those of the sieve elements above and below by cytoplasmic connections passing through the pores of the sieve plate.

Nuclei are absent in mature sieve tube elements.

b. **Companion cells:** Generally associated with the sieve tube is a small cell containing dense cytoplasm and a large elongated nucleus. It remains connected with the tube by pores. **Companion cells are absent in ferns and gymnosperms** (fir, cycas, pine).

c. **Bast fibres:** Sclerenchymatous cells occurring in the phloem are bast fibres. These alone are composed of **dead cells.**

d. **Phloem parenchyma:** Ordinary parenchyma occurring along with phloem elements is known as phloem parenchyma. **It is absent in monocot stems.**



Phloem is found in all parts of the plant like roots, stems and leaves.

The sieve tubes are used for the longitudinal transmission of prepared food materials from the leaves to the storage organs and growing parts of the plant.

Phloem fibres (absent in most monocots) provide mechanical strength.

Economic Importance of Fibres

Fibres are thread-like sclerenchymatous tissues obtained from different parts of the plant body. Cotton fibres are, however, made of cellulose. Commercial vegetable fibres may be **floss fibres** like cotton (hairy outgrowths of seeds), **bast fibres** like jute, hemp (sclerenchymatous tissues of the secondary phloem), **coir fibres** of coconut (fibrous husk of coconut fruit) and **leaf fibres** (sclerenchymatous tissues of leaf). These are of great commercial value since the long thick-walled cells make excellent textile fibres.

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Meristematic Tissue

Nature: These are composed of living cells that possess the power of dividing indefinitely.

1. These are spherical, oval or polygonal in shape.
2. The cell wall is thin and made up of cellulose.
3. Inter-cellular spaces are absent due to compact arrangement of cells.
4. Each cell contains a large prominent nucleus.
5. Protoplasm is abundant, hence, vacuoles are either lacking or considerably reduced.
6. They do not store reserve food material.

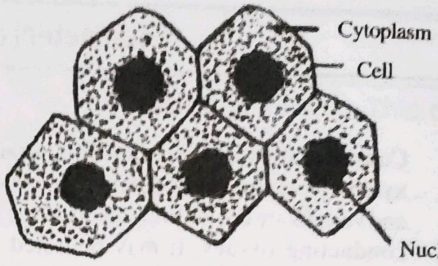
Occurrence and Function: According to their position in the plant, meristems are apical, lateral and intercalary.

a. **Apical meristem:** These are situated at the growing tip of stems and roots. These cells always maintain their nature and position and hence, called **apical initials**. They bring about the **elongation of the root and stem.**

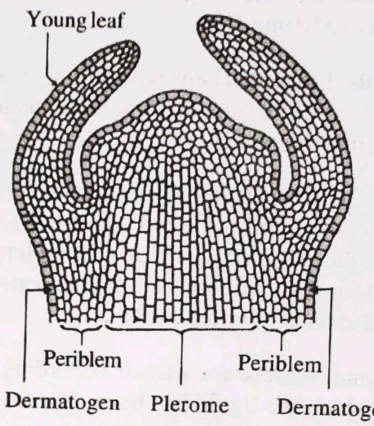
b. **Intercalary:** These meristems become separated from the apex due to the development of permanent tissues in between. It differs from other meristems in that it gets fully utilised in the formation of permanent tissues.

These are located at the base of the nodes (e.g., mint), base of internodes (e.g., grasses) or base of leaf (e.g., pines) These produce an **increase in length** of the organ.

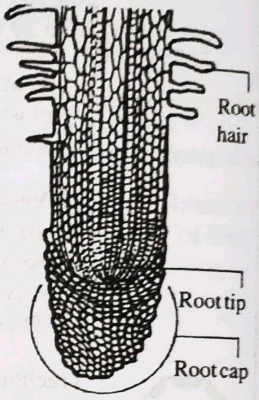
c. **Lateral meristem:** These are found beneath the bark of trees as **cork-cambium** and in the vascular bundles of dicot roots and stem, known as **cambium**. Causes the organ to **increase in diameter** and **girth.**



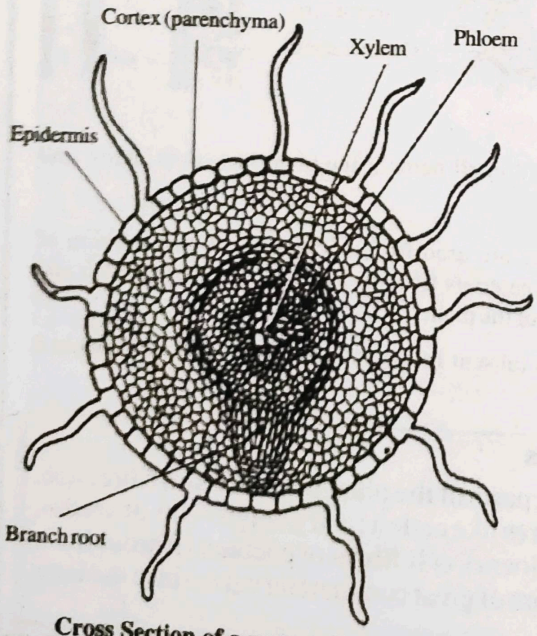
Meristematic Tissue as seen in Cross-sectional View



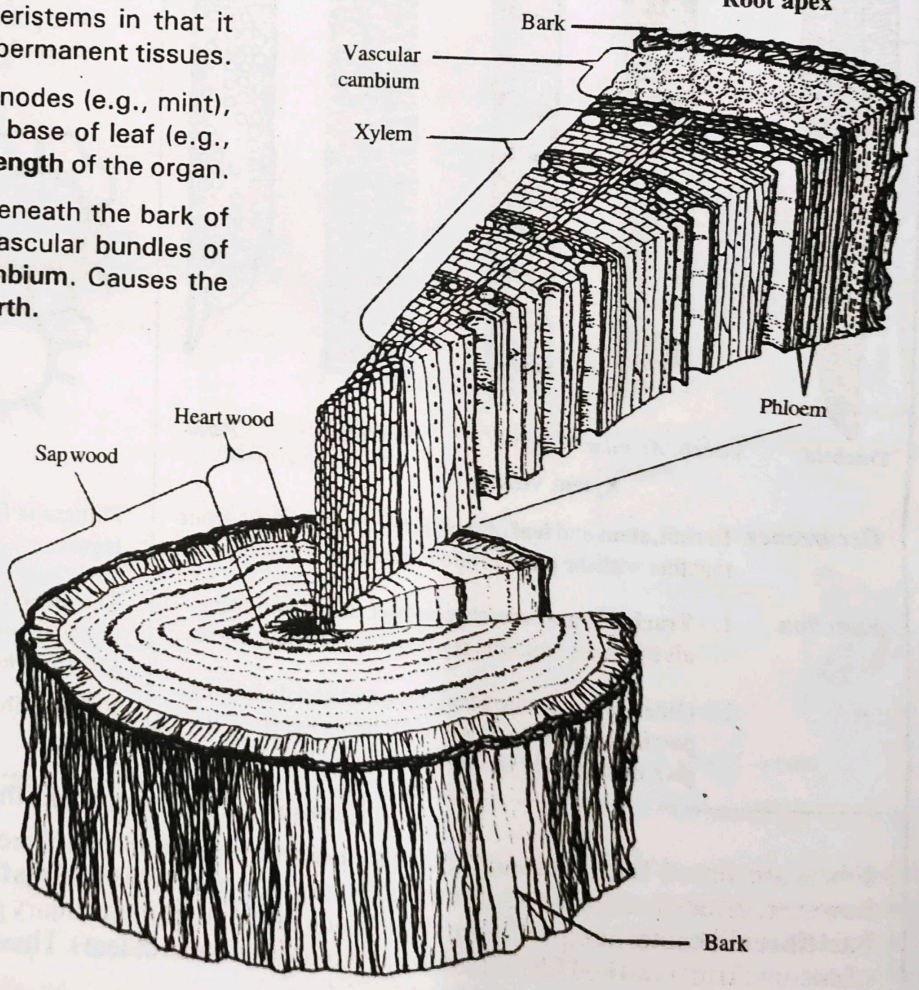
Cross Section of Stem apex



Cross Section of Root apex



Cross Section of a young dicot root



Cross Section of a Tree Trunk

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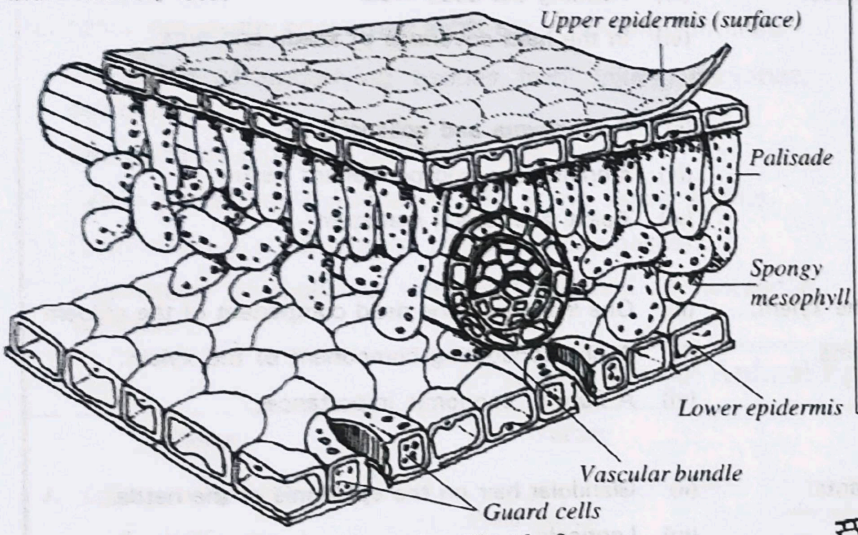
Protective Tissues in Plants

Epidermis

The epidermal tissue system is derived from the apical meristems and forms the outermost, parenchymatous layer which extends over the entire surface of the plant body. It is continuous except for certain openings like the **stomata** (on leaf surface and herbaceous stems) and **lenticels** (on woody stems).

At surface view, the cells of the epidermis are somewhat irregular in outline, closely fitted together without intercellular spaces. The epidermis is mostly single-layered, but may become multi-layered as in the leaves of banyan, oleander, india-rubber, etc.



Section through a Dicot leaf

Main Functions of the Epidermis

1. **Protection** of internal tissues against mechanical injuries, excessive heat or cold and attack of parasitic fungi and bacteria.
   - * The wax present on the upper surface of floating leaves protects them from wetting.
   - * The epidermis often develops **sharp and stiff hair** as in some cucurbits, or **glandular (stinging) hairs** as in nettles which protects it against herbivorous animals.
   - * The epidermis of aroids and cereals has a deposition of **silica** which is abrasive and hence protects against grazing animals.
   - * The epidermis also protects the plant against strong sunlight.
2. **Prevents desiccation of plant:** Prevention of excessive loss of water by evaporation of water from the internal tissues by the development of thick **cuticle** (deposition of cutin), **cutinised hairs, scales, multiple epidermis,** etc. The onion skin becomes thick and water-proof by the addition of **suberin.**

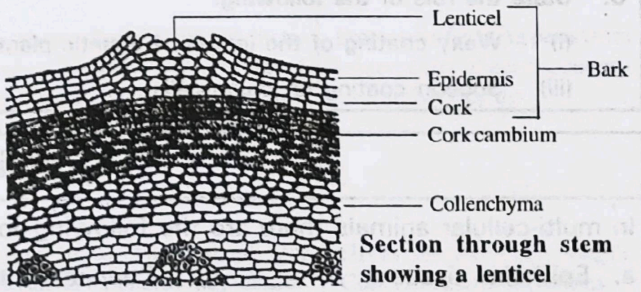
   Under extreme dry conditions, the cuticle is reinforced by a layer of **wax.**

Cork

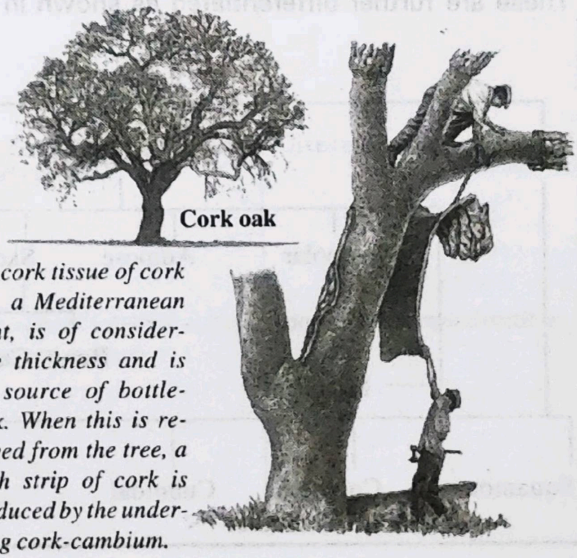
As plants grow older the outer protective tissue undergoes a certain amount of wear and tear. To replace or to reinforce the peripheral protective tissues, particularly the epidermis of stems, a strip of secondary meristem, called **cork-cambium** arises in that region. The cork-cambium commonly originates in the outer layer of the collenchyma.

The new cells cut off by the cork-cambium on its outer side are roughly rectangular in shape and form the **cork** or **phellem** of the plant. Cork cells are dead, suberised (hence, impervious to water), and thick-walled. It is highly compressible, a bad conductor of heat and electricity and absorbs sound and vibrations.

1. It protects the inner tissues from mechanical injury and against the attack of microorganisms.
2. Being suberised, cork protects internal tissues from loss of moisture as well as from entry of water.
3. It provides insulation from extremes of temperature.
4. The lenticels are aerating pores present on the outer surface of cork through which exchange of gases take place.



Section through stem showing a lenticel



The cork tissue of cork oak, a Mediterranean plant, is of considerable thickness and is the source of bottle-cork. When this is removed from the tree, a fresh strip of cork is produced by the underlying cork-cambium.

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Exercise 1

1. Define a tissue.
2. a. Arrange the following terms in the correct sequence of development.

   Organism, cell, organ system, tissue, organ, tissue system

   b. Select the term given in 2 (a) to describe the following:

   (i) Bacteria (ii) Leaf (iii) Amoeba

   (iv) Tree (v) Roots (vi) Unicellular root hair
3. **Name the tissue found:**

   (i) In the mesophyll of leaves. (ii) In the veins of leaves.

   (iii) At the growing tips of root, stem and leaves. (iv) Forming the body wall.

   (v) Below epidermis in dicot stems. (vi) In the hard coverings of seeds and nuts.
4. **Distinguish between:**

   (i) Cell and tissue (ii) Parenchyma and collenchyma

   (iii) Sclerenchyma and parenchyma (iv) Meristematic and permanent tissue

   (v) Collenchyma and sclerenchyma (vi) Apical and lateral meristem
5. **Name:**

   (i) One living and one dead component of the xylem. (ii) One living and one dead component of the phloem.

   (iii) The aerating pores present on woody stems. (iv) A non-conducting component of the xylem.

   (v) The two types of sclerenchyma tissues. (vi) A fibre of economic importance.
6. **State the role of the following:**

   (i) Waxy coating of the leaves of aquatic plants. (ii) Glandular hair on the epidermis of the nettle.

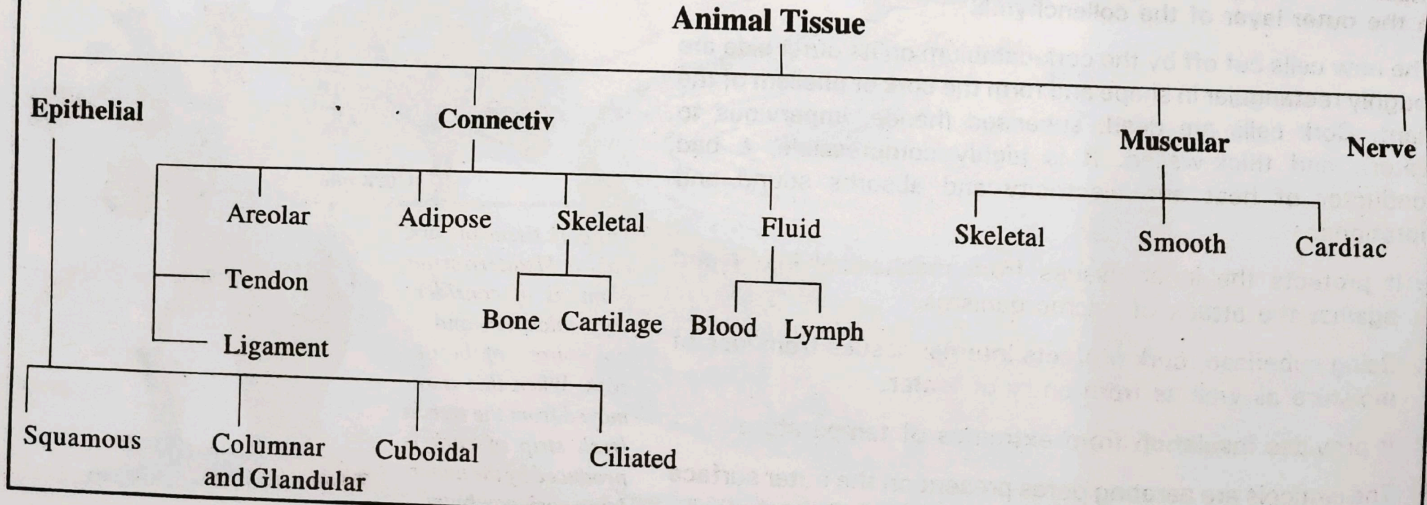
   (iii) Suberin coating on onion cells. (iv) Lenticels

Animal Tissues

In multi-cellular animals there are the following four main types of tissues:

a. Epithelial tissue b. Connective tissue c. Muscular tissue d. Nerve tissue

These are further differentiated as shown in the chart below:



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Epithelial Tissue

The epithelial tissue is composed of one or more layers of cells which cover the external and internal body surface.

* The cells lie closely connected with **no intercellular spaces,** on a thin gelatinous membrane and adhere to each other with considerable force.
* The free surface of the cells may be smooth or may have hair-like cytoplasmic extensions such as **cilia** or **microvilli.**
* Epithelial tissue may be **simple,** i.e., composed of a single layer of cells, or **stratified,** i.e., made up of several layers.
* Blood vessels are absent in epithelial tissues.

Epithelial tissue are concerned with the following function:

* Protection of underlying tissues from injury, microbes, desiccation.
* Secretion of enzymes and hormones.
* Sense perception by sensory cells lining sense organs.
* Respiration (i.e., exchange of respiratory gases).
* Absorption of digested food and removal of metabolic wastes.

Types of Epithelial Tissue

According to the shape of cells, four main types of epithelial tissue are recognised.

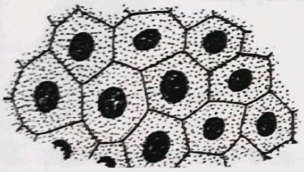
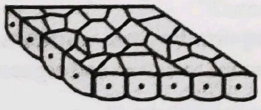
a. Squamous epithelium
b Cuboidal epithelium
c. Columnar and glandular epithelium
d. Ciliated epithelium

Glandular Epithelium

Glandular epithelium

The columnar epithelium is often modified to form glands which secrete chemicals. The modification may be a single cell becoming large and goblet-shaped or several cells, i.e., the epithelial tissue folding inwards to form flask-shaped (alveolar) or tubular glands.

Characteristics of Animal Epithelial Tissue

Tissue	Nature	Occurrence	Function
1. Squamous Epithelium 	Compact, flat plate-like cells with no inter-cellular spaces.	Lining the skin and cavities of ducts. Whenever it forms a lining as that of blood vessels, it is called by the special name of **endothelium.**	Protects underlying parts from injury, entry of germs, chemicals and drying up.
2. Columnar and glandular epithelium	Cells are taller than broad with nucleus towards the base. Certain cells adapted for secretion.	Intestinal lining, sweat gland, tear gland, salivary gland, kidney tubules.	Gives mechanical strength. Concerned with secretions.
3. Cuboidal epithelium 	Cube-like cells which are square in section but the free surface appears hexagonal.	Kidney tubules, salivary glands, inner lining of the cheek.	Gives mechanical strength.
4. Ciliated epithelium	Cuboid or columnar cells with protoplasmic outgrowth called cilia.	Lining of trachea of vertebrates, kidney tubules, and oviduct.	Keeps out unwanted particles.

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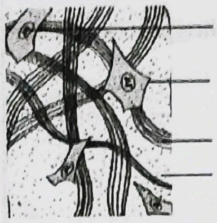
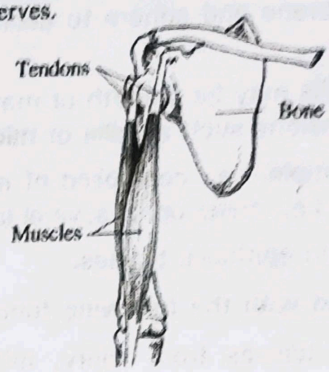
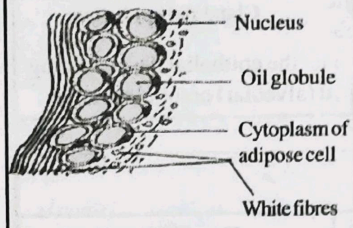
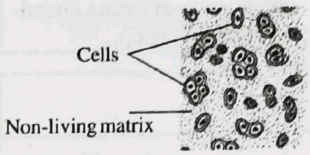
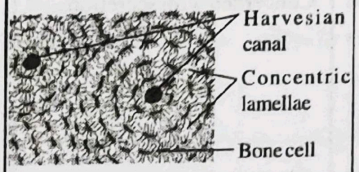
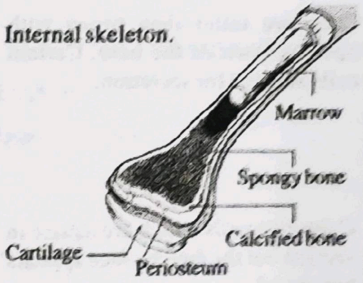
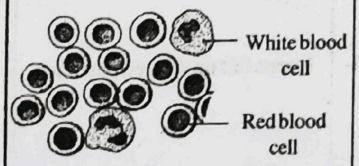
Animal Connective Tissue

Tissue	Nature	Occurrence	Function
1. Areolar Connective 	Consists of white and yellow fibres with irregular cells scattered in the matrix	Fills spaces inside organs found around muscles, blood vessels and nerves.	Joins skin to muscles, supports internal organs, helps in the repair of tissues.
2. Tendon	Consists of collagen bound together by areolar connective. **Inelastic.**		Connects muscles to bones.
3. Ligament	Consists of elastic (yellow) fibres bound together by areolar connective. **Elastic.**		Connects bones to each other.
4. Adipose Tissue 	Oval or rounded cells filled with fat droplets.	Below skin; between internal organs; yellow bone marrow.	Storage of fat. Conserves heat.
5. Skeletal Tissue			
a. Cartilage 	**Non-porous tissue,** intercellular matrix composed of proteins, slightly hardened by calcium salts. **Blood vessels absent.**	Ear pinna, nose tip, epiglotis, intervertebral disc of mammals. Rings of trachea.	Provides support and flexibility to body part.
b. Bone 	Hard, **porous tissue** impregnated with phosphates and carbonates of calcium and magnesium. **Blood vessels present** (bone marrow).	Internal skeleton. 	Protects internal delicate organs; provides attachment for muscles; helps in locomotion; bone marrow makes blood cells.
6. Fluid Tissue			
a. Blood 	Consists of a fluid - plasma and formed elements **erythrocytes** (red blood cells), **leucocytes** (white blood cells) and **platelets.** Dissolved in the plasma are proteins, salts, hormones and enzymes.	In blood vessels circulating throughout the body.	Transports oxygen, nutrients, hormones to tissues and organs. **Leucocytes** fight diseases. **Platelets** help in clotting of blood.
b. Lymph	Straw-coloured fluid similar to blood in composition but devoid of RBC's and proteins.	In lymph vessels.	Transports nutrients into the heart. Forms the defence system of the body.

Note:
The fat may occur as a single large droplet surrounded by a small amount of cytoplasm (as in white adipose), or as a suspension of tiny droplets in a dense cytoplasm (as in brown adipose). **Brown fat** is particularly found in new-born mammals. The brown fat cells contain more mitochondria and hence have a larger capacity for generating heat. Thus, new born mammals do not shiver inspite of lower temperatures outside the womb.

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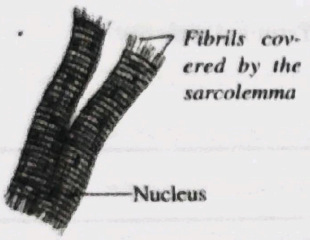
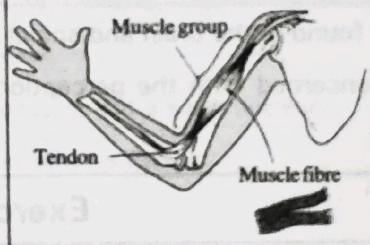
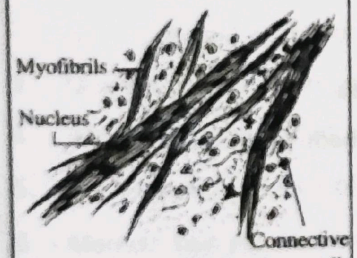
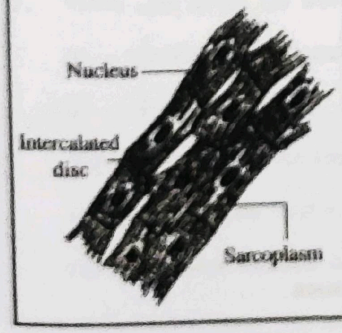
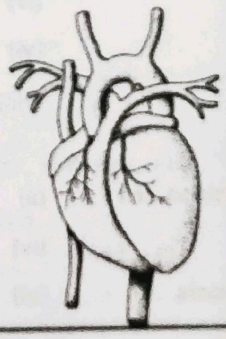
Points to Note

1. The connective tissue is concerned with "connecting" the parts of the body. As such it can connect bones to each other, muscles to bones, bind tissues, and give support to the various parts of the body by forming a packing around organs so that they do not get displaced by body movements.
2. Fluid tissues connect the different parts and also maintain a continuity within the body. They differ from other connective tissues in the following ways:
   (i) The intercellular matrix is a fluid called plasma.
   (ii) Fibres are absent.
   (iii) The cells of fluid tissues (corpuscles) are freely suspended in the plasma.
3. Blood platelets are not cells but pieces of certain giant cells of the bone marrow. They are rounded, colourless, bi-convex and non-nucleated. They disintegrate at the site of injury and help in the clotting of blood.

Red blood cells	White blood cells
1. Circular, bi-concave in shape.	Irregular or amoeboid in shape.
2. Coloured red due to pigment haemoglobin.	Colourless due to absence of pigments.
3. Occur in very large numbers (approx. 4 to 6 million per cubic mm).	Less numerous than RBC's (approx. 8,000 per cubic mm).
4. Concerned with oxygen transport.	Protect body against infection.

Tendon	Ligament
1. Inelastic	Elastic
2. Join muscle to bone	Bind bones together
3. Made up of white fibres.	Made up of yellow fibres

Animal Muscle Tissue

Muscle	Nature (Microscopic appearance)	Occurrence	Function
1. **Skeletal muscle (or voluntary, striped)** 	Striated, multi-nucleated, unbranched fibres. The muscle fibre shows alternate dark and light stripes and is enclosed in a thin, definite membrane called **sarcolemma.** Longitudinal myofibrils are the contractile elements. These muscles can get tired and need rest.	Attached primarily to bones. 	Provide the force for locomotion and all other voluntary movements of the body.
2. **Smooth muscle (involuntary or visceral muscle)** 	Non-striated, uni-nucleated, spindle shaped fibres. The nucleus is in the centre and the ends of the cell may branch. **Myofibrils** run longitudinally through the cell. The muscle fibre lacks surrounding membrane but several fibres are joined together in bundles by loose connective tissue.	Occur in sheets in the walls of hollow viscera like stomach, intestines ; blood vessels, iris, erector muscle in skin.	Unstriated muscles cause slow and prolonged contractions which are involuntary, i.e., not under the control of the will.
3. **Cardiac muscle** 	Striated, uni-nucleated, branched fibres. Cardiac muscles show characteristics of both unstriated and striated muscles. Each fibre is surrounded by **sarcolemma** and has cytoplasm (sarcoplasm) with longitudinal myofibrils and a centrally located nucleus. They contract rapidly but rhythmically and involuntarily throughout life. Cardiac muscle does not tire.	Occurs only in the heart. 	The contraction and relaxation of the heart muscles help to pump the blood and distribute it to the various parts of the body.

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Unstriated Muscle	Striated Muscle
1. Muscle contractions are involuntary.	Contractions are voluntary.
2. Muscle contractions are slow and prolonged.	Contractions are rapid and powerful.
3. Muscles do not have stripes or striations.	Muscles have stripes or light and dark bands.
4. Cells may be branched.	Cells are unbranched.
5. Single, centrally located nucleus.	Several nuclei present.
6. Fibres do not have membrane enveloping it.	Each fibre is enclosed in membrane called sarcolemma.

Nervous Tissue

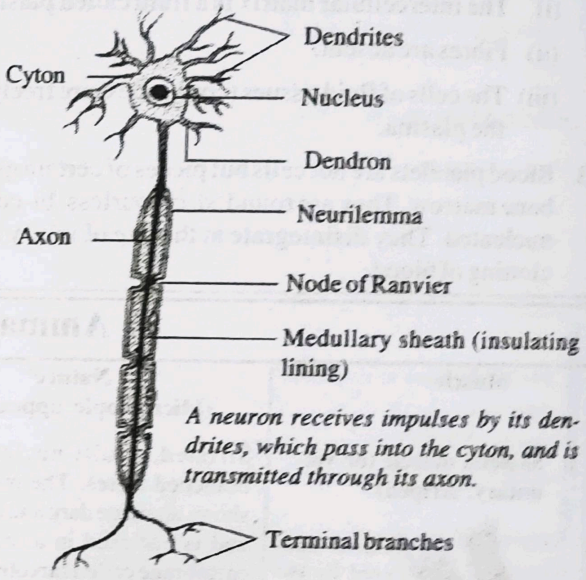
A group of specialised cells, with highly developed properties of irritability and conductivity form the nervous tissue. These cells called neurons, are the fundamental units of the nervous system and possess the ability to receive stimuli from within or outside and send impulses to different parts of the body.

Each cell consists of three parts; the **cyton** or the cell body, the dendrons which are short processes arising from the cyton and further branching into thin dendrites, and the **axon** which is a single long cylindrical process forming fine branches terminally.

*Neurons enclosed in sheaths form a **nerve fibre** and nerve fibres bound together in parallel bundles form a **nerve.***

Occurrence: Nerve cells are found in the brain and spinal cord.

Function: Nerve tissue is concerned with the perception and responsiveness of animals.



A Neuron

Exercise 2

1. Mention the general characteristics of the epithelial tissue.
2. **Name the type of tissue found:**
   - (i) Forming the body wall.
   - (ii) In the rings of trachea.
   - (iii) Lining the wind pipe or trachea.
   - (iv) In between the vertebra of mammals.
   - (v) In the brain.
   - (vi) Enveloping bones and connecting them to muscles.
3. **Name one place in living organisms where the following tissues are located:**
   - (i) Nervous tissue
   - (ii) Squamous epithelium
   - (iii) Glandular epithelium
   - (iv) Areolar connective tissue
   - (v) Adipose tissue
   - (vi) Columnar epithelium
   - (vii) Cardiac muscle
   - (viii) Cuboidal epithelium
4. **Differentiate between:**
   - (i) Red blood cell and White blood cell
   - (ii) Blood and lymph
   - (iii) Tendon and ligament
   - (iv) Bone and cartilage
   - (v) Striated and unstriated muscle
   - (vi) Fluid tissue and other connective tissues

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Exercise 3 (Miscellaneous)

1. **Identify the tissue from the description given:**
   - (i) Cell wall unevenly thickened with cellulose at corners.
   - (ii) Occurs below epidermis in stems.
   - (iii) It has thin, cellulose cell wall.
   - (iv) Conducts water and minerals from the root to the leaves.
   - (v) Cuboid or columnar cells, lining the trachea of vertebrates.
   - (vi) Found beneath the bark and causes the organ to increase in diameter.
   - (vii) Hard porous tissue impregnated with calcium and magnesium salts.
   - (viii) Occurs only in the heart.
   - (ix) Cells are taller than broad, with nucleus towards the base.
   - (x) Cell wall evenly thickened with lignin.
2. **State whether the following statements are true or false:**
   - (i) Nuclei are absent in mature sieve tube elements.
   - (ii) Except xylem parenchyma, all other elements at maturity consist of dead cells.
   - (iii) Companion cells are absent in the phloem of ferns and gymnosperms.
   - (iv) Intercalary meristem is found beneath the bark of trees.
   - (v) The cells of meristematic tissues have prominent vacuoles and a small nucleus.
   - (vi) A single large vacuole is present in the cells of sclerenchyma tissues.
   - (vii) Blood vessels are present in cartilage tissue.
   - (viii) The areolar connective tissue joins skin to muscles and supports internal organs.
   - (ix) Leucocytes help in clotting blood.
   - (x) Cuboidal epithelium is found in the inner lining of the cheek.
3. Mention one similarity and one difference between smooth muscles and the cardiac muscle.
4. Why is blood regarded as a connective tissue?
5. State the significance of brown fat.
6. Mention two peculiarities of the cardiac muscle.
7. **Write one word for the following:**
   - (i) Cells of the tissue capable of cell division.
   - (ii) A group of cells performing a specific function.
   - (iii) Tissues concerned with the transportation of food, water, minerals, etc.
   - (iv) Structures within a cell concerned with different functions.
   - (v) Several tissues collectively performing the same function.

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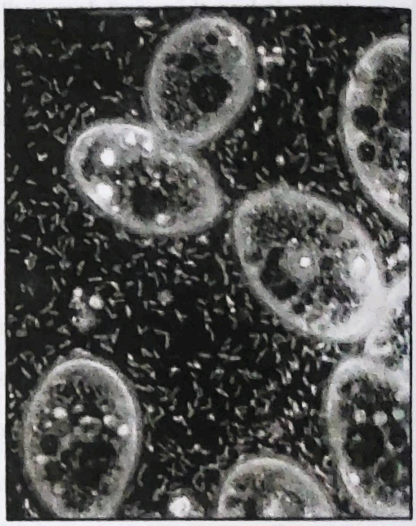
3

Diversity in the Living World

Introduction

In 1758, **Carl Linnaeus** suggested that all living organisms be put into two groups, the **plant kingdom** and the **animal kingdom.** However, biologists have since discovered that there are a number of tiny organisms that do not belong to either kingdom.



Bacteria seen under a microscope

* In 1866 the German zoologist, **E. H. Haekel** introduced a third group, kingdom **Protista** to include organisms that have a **single eukaryotic cell.** This kingdom contains species claimed by both botanists and zoologists and some groups with no clear relationship to any species. It contains a number of organisms previously classified as plants, animals or fungi, for example, ***diatoms, amoeba, euglena, kelp*** (a giant seaweed).
* In 1969 **Robert Whittaker** proposed a fourth kingdom, **Monera.** A moneran cell is a simple **prokaryotic cell.** This kingdom includes **microscopic bacteria** which act as decomposers, **macroscopic blue-green algae** etc.
* Whittaker also proposed a fifth kingdom, **Fungi.** Organisms included in this category **lack chlorophyll** and are **parasites** or **saprophytes. Mushrooms, toadstools, bread moulds** and **lichens** belong to this kingdom.

A part of the traditional and modern systems of classification are shown below to illustrate the dynamics of classification.

Kingdom Plantae (Traditional classification)

Cryptogams (Non-flowering plants)			Phanerogams (Flowering plants)	
Thallophyta	**Bryophyta**	**Pteridophyta**	**Gymnosperms**	**Angiosperms**
Algae	Mosses	Ferns	Cycadales	Monocotyledons
Fungi	Liverworts	Club mosses	Coniferales	Dicotyledons
Lichens	Hornworts	Horsetails		

Bacteria and virus are difficult to group in the above classification.

Living Organisms (Modern classification)

Kingdom Monera	Kingdom Protista	Kingdom Fungi	Kingdom Plantae			Kingdom Animalia
			Cryptogams		Spermatophyta	
Bacteria	Algae (except blue-green algae)	Fungi	**Bryophyta** : Mosses, Liverworts		Gymnosperms	
Cyano-bacteria	Protozoa	Lichens	**Lycopodophyta** : Club mosses		Angiosperms	
Blue-green algae	Slime Moulds		**Filicinophyta** : Ferns			
			Sphenophyta : Horsetails		Monocotyledons	Dicotyledons

Virus still does not find a place in the above classification.

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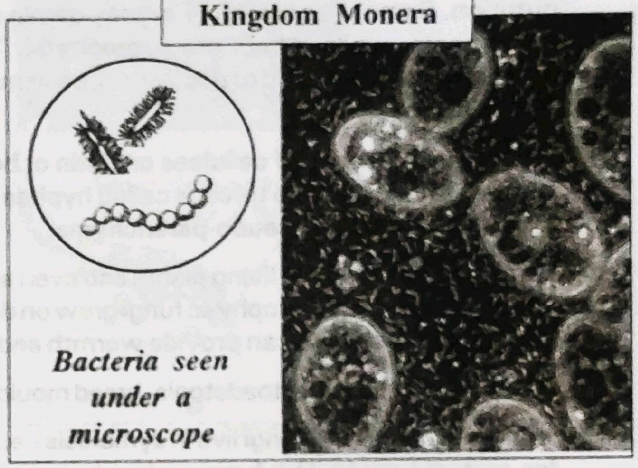
Classification of Plants

Plants exhibit tremendous diversity in size, form, colour, organisation, distribution and life history.

Kingdom Monera



Bacteria seen under a microscope

1. **Kingdom Monera**

   Monerans are the most primitive group of living organisms. This kingdom includes tiny, microscopic organisms like **bacteria**.

   The bacteria are microscopic, unicellular, asexually reproducing organisms lacking in nuclear membrane and chlorophyll. They lead either a saprophytic or parasitic mode of existence.

2. **Kingdom Protista**

   Protista includes organisms that have a **single cell.**

   This kingdom contains species claimed by both botanists and zoologists and some groups with no clear relationship to any species. It also contains a number of organisms previously classified as plants, animals, algae or fungi.

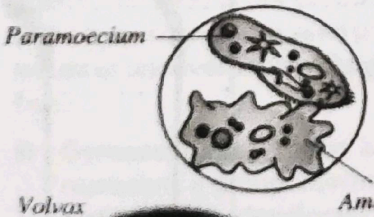
   Example: Diatoms, amoeba, paramoecium, euglena, volvox, kelp (a giant seaweed)

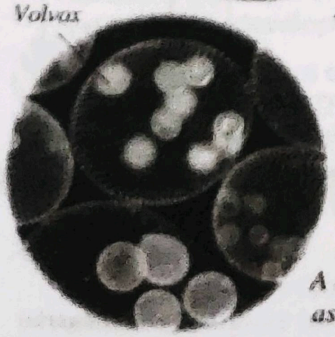
   Algae occur as fresh water species found in ponds and ditches or marine species commonly known as sea-weeds. They range from the single-celled to colonial forms and filamentous types.

   The cell-wall is of cellulose and the body composed of true parenchymatous tissue. Reserve food is generally **starch.**

   Algae contains chlorophyll, a green pigment, that assists in the synthesis of food. However, presence of other pigments often masks the chlorophyll and imparts colours like blue, brown and red to the algae.

Kingdom Protista





A colony of green alga volvox, as seen under the microscope.

***Algae** (singular: alga) are **green** and can make their own food.*

*They may vary in size from the **single-celled chlamydomomas** to the giant **laminaria** which can measure upto 10 metres in length.*

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3. Kingdom Fungi

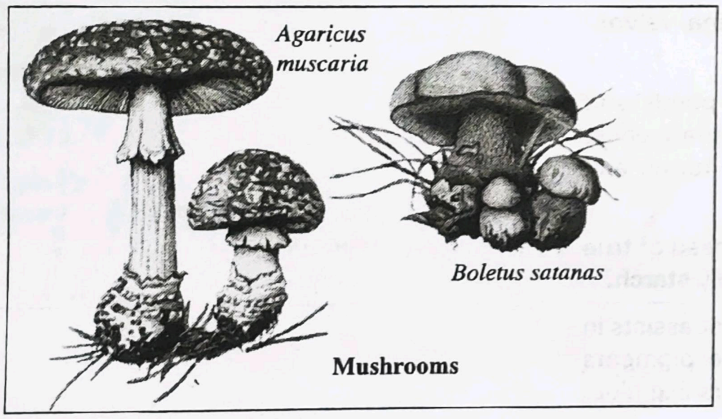
Fungi are characterised by the absence of chlorophyll. Being non-green, they are **heterotrophic** and have diverse modes of nutrition. Some are **parasitic**, i.e. they derive nutrition from living hosts, while others are **saprophytic**. These absorb prepared food from dead or decaying organisms. The reserve food is **glycogen**.

The cell wall is made of **cellulose or chitin** or both. The body is a web of fine delicate threads called hyphae, is composed of false tissue called **pseudo-parenchyma**.

Parasitic fungi grow on living plants and even animals including human beings. Saprophytic fungi grow on dead, decaying organic matter which can provide warmth and food.

Example: Mushrooms, toadstools, bread moulds and lichens.

In **lichens**, algae and fungi live in **symbiosis** i.e.,they co-exist for mutual benefit.The fungus absorbs water and mineral matter and supplies it to the algae. The alga, in turn, prepares food and supplies it to the fungus.



Mushrooms

	Algae	Fungi
1.	Contain chlorophyll.	Chlorophyll absent. Hence non-green.
2.	Autotrophic i.e. prepare own food.	Heterotrophic i.e. depend on others for food.
3.	Body made of true parenchyma.	No true tissues present.
4.	Cell wall is of true cellulose.	Cell wall contains substances like chitin, callose, pectose etc.
5.	Live in aquatic surroundings.	Live on living or dead organisms.
6.	Reserve food is starch.	Reserve food is glycogen.

Virus

Viruses lack cellular structure and possess a regular geometrical organisation. Its core consists of only one type of nucleic acid (DNA or RNA) and is surrounded by a protein shell. They are submicroscopic and their size ranges between 10 and 250 mμ.

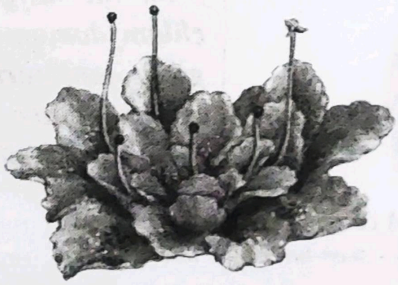
Viruses are parasites and outside the host body they are inactive. Inside the cell, the virus DNA or RNA controls the biochemical activities of the cell and reproduces its own kind. Viruses are found infecting plants, animals and bacteria.

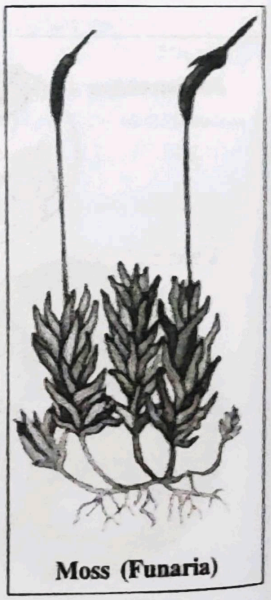
4. Kingdom Plantae

Cryptogams: This division of the plant kingdom comprises **"flowerless"** and **"seedless"** plants. The main groups are bryophyta (mosses) and pteridophyta (ferns).

(i) **Bryophyta:** Plants belonging to this group (mosses and liverworts) lack true vascular tissue. The plant body is flat and from its underside root-like growths called **rhizoid** anchor it to the substrate. The upper surface of the body produces a stalk which bears a **capsule** at its end. Spores are borne in the capsule. Reproduction is by **asexual** and **sexual methods.**

These liverworts are low growing plants and look like pieces of green ribbon. As the plant grows forwards, the ribbon keeps dividing in two.




Moss (Funaria)

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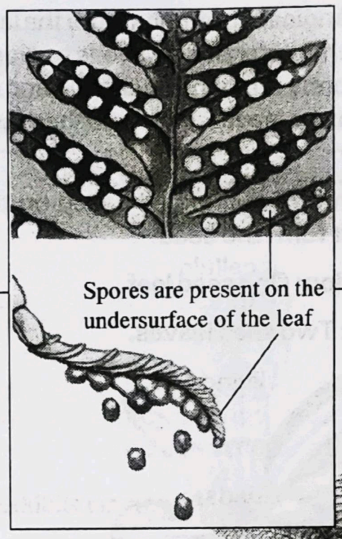
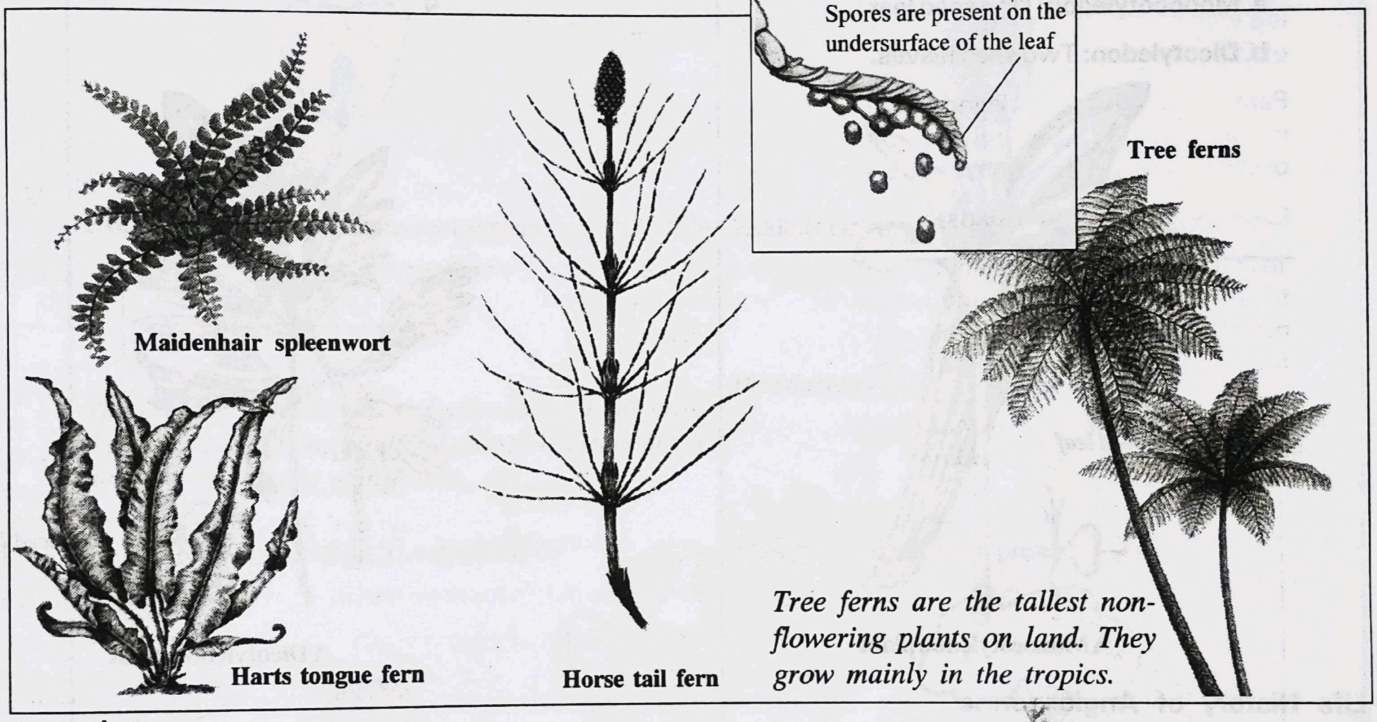
(ii) **Pteridophyta:** This group is the most highly evolved among the cryptogams. Vascular tissues are present and the plant body is differentiated into **root, stem and leaves.** The leaves are often made up of leaflets and are referred to as **fronds. Spores are borne on the undersurface of the leaf.** Spores help in reproduction.

Ferns generally inhabit shady or damp places, although some grow in dry areas.





Spermatophyta

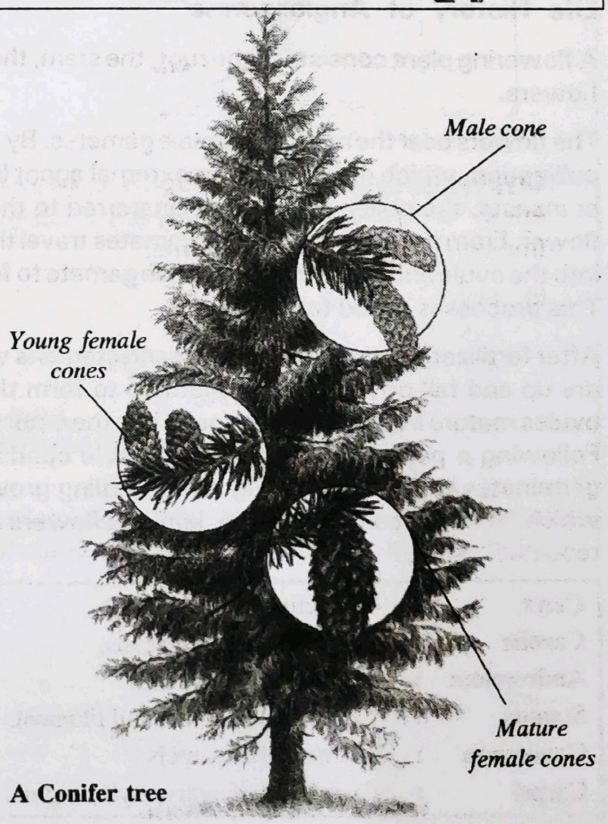
This division comprises plants which bear flowers and seeds and make up the majority of the larger plants. Seed is formed as a result of sexual reproduction.

The male and female gamete fuse (unite) inside the ovary (female part of the flower) and develop into the seed. In some plants, the seed is not produced inside an ovary. This results in the major division in seed plants called **Gymnosperms** (seed naked or uncovered) and **Angiosperms** (seed enclosed within fruit)

(i) **Gymnosperms:** These are either trees or shrubs and represent a group intermediate to the lower plant forms and the highly developed angiosperms.

The male flower is a cone called **microsporophyll** which produces the pollen. The female flower is much larger and consists of a rosette of carpels or **megasporophylls** alternating with the leaves. The carpels are always open and ovules are borne, freely exposed on the two margins of the carpel.

Cycads are found in abundance in the warm humid tropics while the **conifers** inhabit the cool temperate mountain tops.



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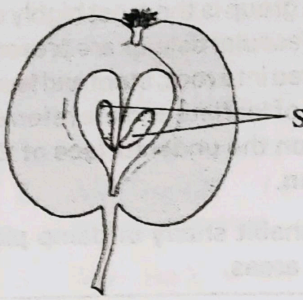
(ii) **Angiosperms:** Angiosperms constitute the largest group of plants and are characterised by seeds enclosed within the fruit. The plant body is highly developed and differentiated into roots, stem and leaves. Flower is the reproductive part of the plant.



Seeds are enclosed within the fruit

Further division of this group is based on the number of cotyledons that form the seed.

a. **Monocotyledon:** One seed leaf

b. **Dicotyledon:** Two seed leaves.

A Monocotyledon plant

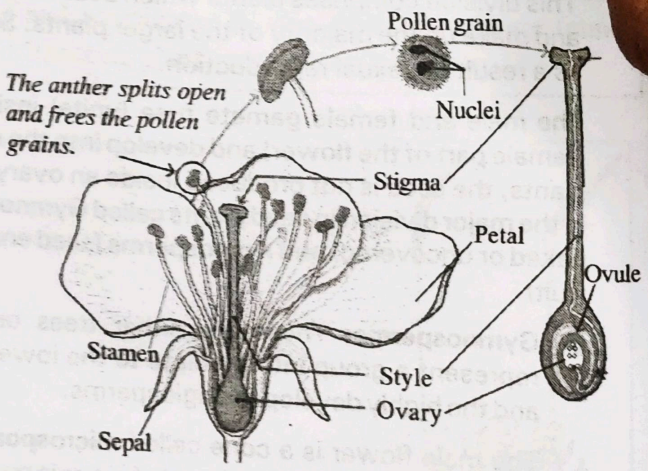
A Dicotyledon plant

Life History of Angiosperms

A flowering plant consists of the root, the stem, the leaves and the flowers.

The flowers bear the male and female gametes. By a process called **pollination**, which may require an external agent like wind, water or insects, the pollen grains are transferred to the stigma of the flower. From the stigma, the male gametes travel through the style into the ovule and fuse with the female gamete to form the **zygote**. This process is called **fertilization**.

After fertilization, the calyx, corolla and stamens wither away i.e. dry up and fall off. The ovary matures to form the **fruit** and the ovules mature into **seeds**. Each seed has the embryonic plant in it. Following a period of rest, under suitable conditions, the seed germinates to form a **seedling**. The seedling grows into a plant, which, in turn, bears root, stem, leaf and flowers and the cycle is repeated.



Pollination taking place in a Flower

Calyx	:	Collective term for sepals.
Corolla	:	Collective term for petals.
Androecium	:	Composed of stamens.
Stamen	:	Composed of anther and filament.
Gynoecium	:	Composed of carpels.
Carpel	:	Composed of ovary, style, stigma.

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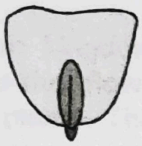
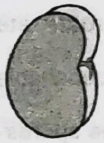
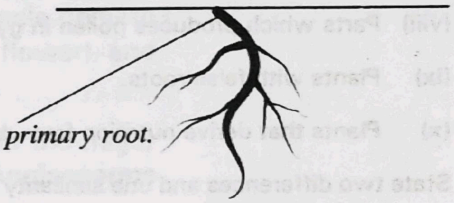
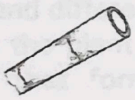
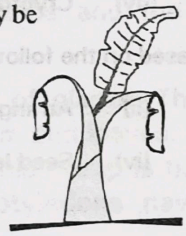
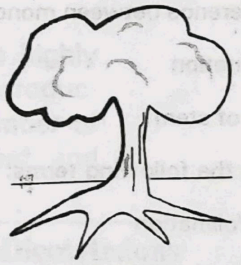
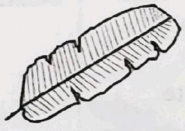
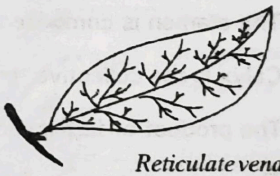
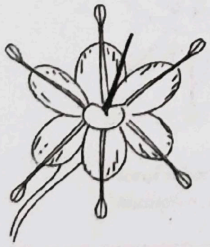
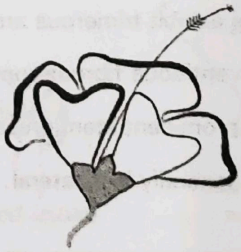
External Differences between Monocotyledons and Dicotyledons

Plant Part	Monocotyledon	Dicotyledon
1. Seed	Consists of a single cotyledon or seed leaf. 	Consists of two cotyledons or seed leaves. 
2. Root	Exhibits adventitious fibrous root system. *The primary root shrivels and adventitious roots arise from the base of the stem. Lateral roots reach same length and acquire a bushy appearance.*	Exhibits tap root system.  *Prominent primary root.*
3. Stem	Generally weak-stemmed. The stem may be  *Hollow e.g. bamboo.* *Reduced to a disc e.g. onion, garlic*  *False (pseudo) stem e.g. banana, canna*	Strong, prominent stem present. 
4. Leaf	The leaf is radical or sessile , isobilateral (i.e.both surfaces equally exposed to light) with parallel venation. *Radical i.e. arises directly from soil* *Sessile i.e. without petiole*  *Parallel venation e.g. banana*	The leaf is petiolate, dorsiventral (upper surface exposed to sunlight) with reticulate venation.  *A petiolate dorsiventral leaf* *Reticulate venation e.g. Hibiscus*
5. Flower	The flowers generally exhibit a trimerous arrangement of floral parts i.e.the whorls are in multiples of three. 	The flowers generally exhibit a pentamerous arrangement of floral parts i.e. the whorls are in multiples of five. 

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Exercise

1. Give one term for
   - (i) Plants with seed enclosed within the fruit.
   - (ii) Plants in which spores are borne in capsules.
   - (iii) Plants that have roots, stem, leaves but no flowers.
   - (iv) Plants with soft perishable stem.
   - (v) Plants which have spores on the undersurface of the leaf.
   - (vi) Plants that lack a cellular structure.
   - (vii) Plants that exhibit a symbiotic relationship.
   - (viii) Parts which produces pollen in gymnosperms.
   - (ix) Plants with false roots.
   - (x) Plants that derive nutrition from dead or decaying matter.
2. State two differences and one similarity between each pair
   - (i) Algae and fungi
   - (ii) Angiosperms and gymnosperms
   - (iii) Bryophyta and pteridophyta
   - (iv) Cryptogams and spermatophyta
3. State the difference between monocots and dicots based on the following features:
   - (i) Leaf venation
   - (ii) Arrangement of petals
   - (iii) Nature of stem
   - (iv) Seed leaves
4. a. Explain the following terms:
   - (i) Pollination
   - (ii) Fertilization

   b. State whether the following statements are true or false. Correct the incorrect statements.
   - (i) Androecium is the female part of an angiosperm flower.
   - (ii) The stamen is composed of ovary, style, stigma.
   - (iii) Calyx is the collective term for petals.
   - (iv) The product of fertilization is called zygote.
   - (v) The ovary matures to form the fruit.
5. From the characteristic mentioned identify as either Monocot or Dicot:
   - (i) Leaf is petiolate, with reticulate venation.
   - (ii) Flowers exhibit trimerous arrangement of floral whorls.
   - (iii) Has adventitious fibrous root system.
   - (iv) Strong prominent stem present.
   - (v) Leaf is generally isobilateral.

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4
Flowering Plants

Introduction

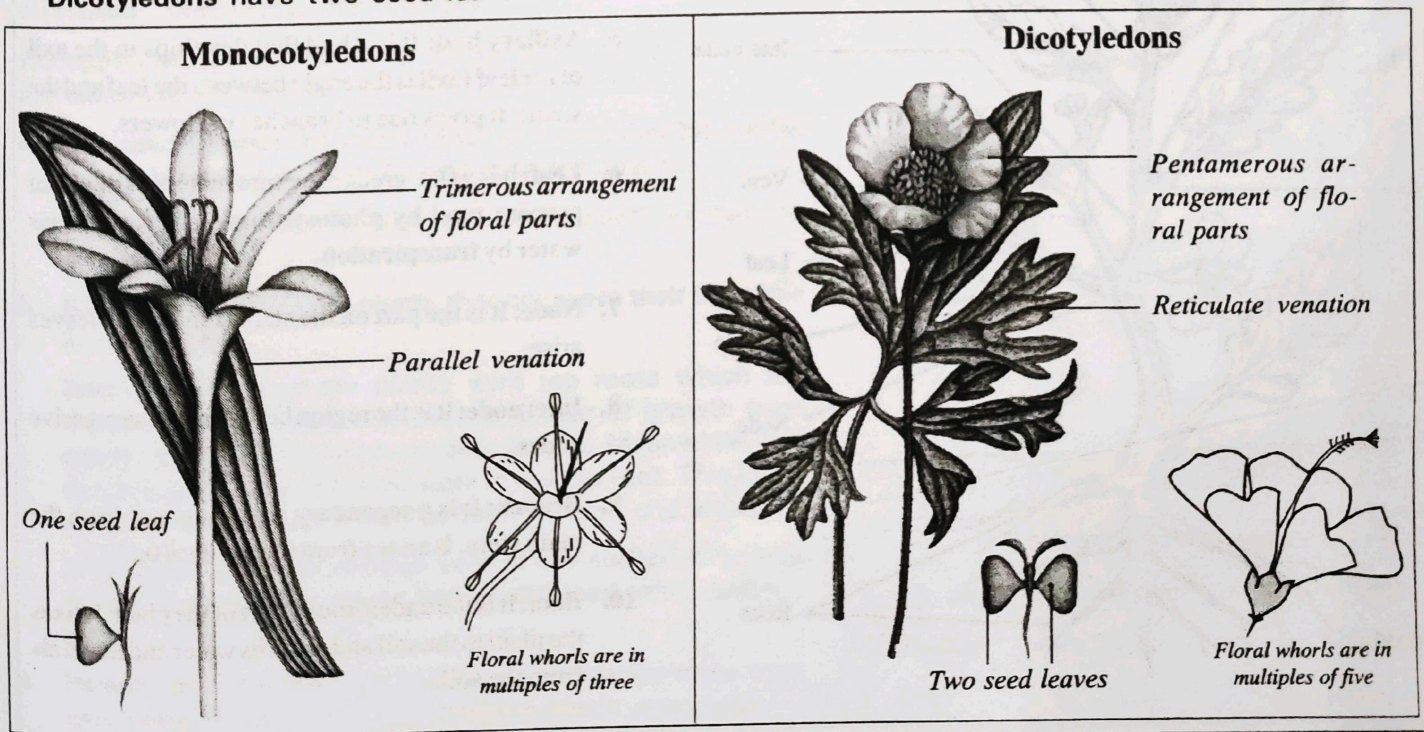
The plant kingdom can be broadly classified into two main divisions-the **flowerless plants** (cryptogams) and the **seed-bearing plants.** The flower is concerned with the sexual reproductive process in higher plants, leading to the formation of **fruits and seeds.**

Seed bearing plants are called **spermatophytes.** Seed is formed as a result of sexual reproduction. The male and female gamete fuse (unite) inside the ovary (female part of the flower) and develop into the seed.

In some plants, the seed is not produced inside an ovary. This results in the major division in seed plants: **Gymnosperms** (seed naked or uncovered) and **Angiosperms** (seed enclosed within fruit).

* **Gymnosperms (Cycads and Conifers)** are either trees or shrubs and represent a group intermediate to the lower plant forms and the highly developed angiosperms.

* **Angiosperms** constitute the largest group of plants. The plant body is highly developed and differentiated into roots, stem and leaves. Flower is the reproductive part of the plant. Further division of this group is based on the number of cotyledons that form the seed: **Monocotyledons** have one seed leaf and **Dicotyledons** have two seed leaves.



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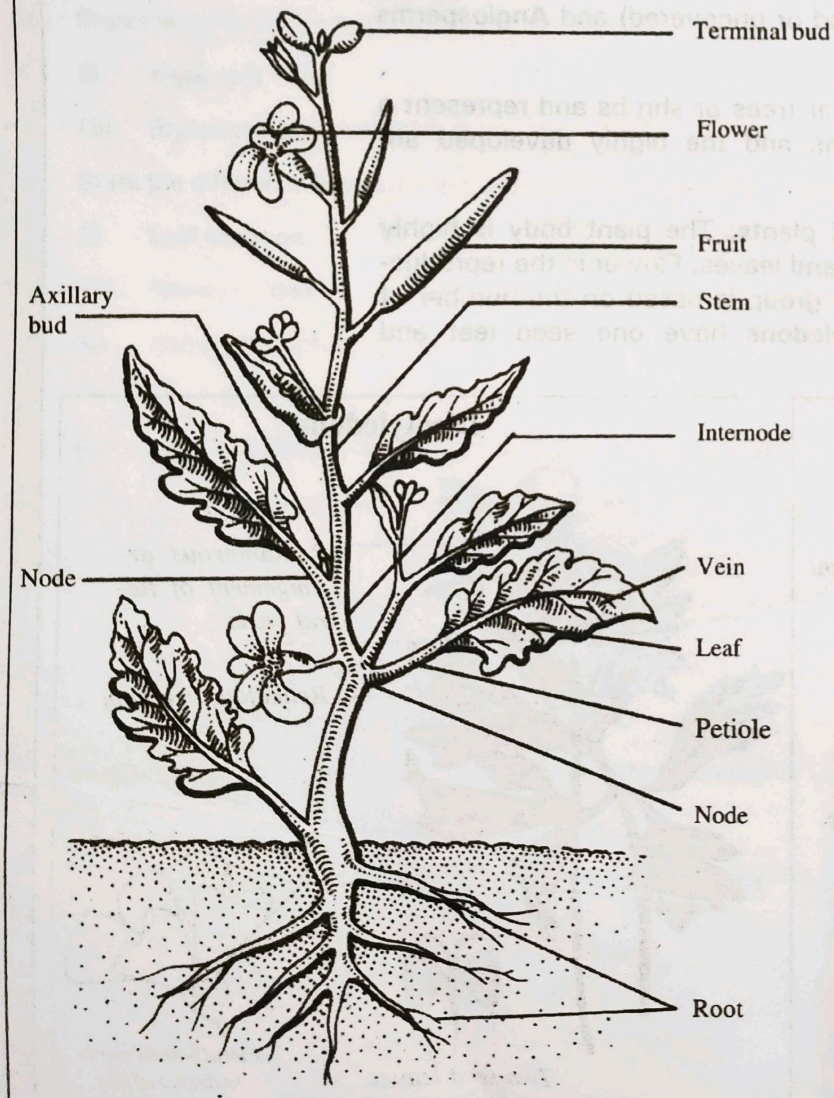
Parts of an Angiospermic Plant

Parts of the plant body mainly concerned with the nutrition and growth are called **vegetative parts.**

The vegetative parts of the plant comprise the **root system** and partly, the **shoot system.**

* The **root system** with its differentiated parts performs two primary functions: fixation and absorption.
* The **vegetative shoot** consisting of the main stem, branches and leaves has mainly three functions: support, conduction and food manufacture (primarily by leaves).
* The **reproductive shoot** is the flower with its differentiated organs. It is essentially concerned with the reproduction of the plant.

Parts of a Flowering Plant



Key

1. **Terminal bud:** It is an undeveloped shoot made up of overlapping leaves. All stems and branches end in a bud.
2. **Flower:** It is the **reproductive part** of the plant. It bears the male and female reproductive parts.
3. **Fruit:** It develops from the flower. The seed contained in it gives rise to a new plant.
4. **Stem:** It is the aerial part of the plant. It holds up the leaves, branches, flowers and fruits.
5. **Axillary bud:** It is a bud that develops in the **axil** of the leaf (axil is the angle between the leaf and the stem). It gives rise to branches or flowers.
6. **Leaf:** It is a flat, green structure that helps the plant prepare food by **photosynthesis** and lose excess water by **transpiration.**
7. **Node:** It is the part on the stem from which leaves arise.
8. **Internode:** It is the region between two successive nodes.
9. **Branch:** It is a secondary stem growing from the main stem. It arises from the axillary bud.
10. **Root:** It is the underground part of the plant. It fixes the plant to the soil and absorbs water and minerals from the soil.

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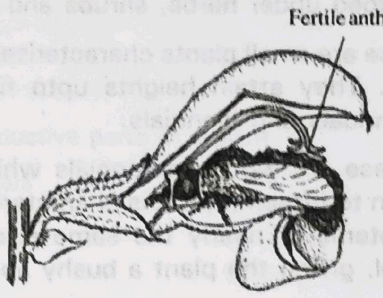
Life History of Flowering Plants

A flowering plant consists of the **root, the stem, the leaves and the flowers.** The flowers bear the male and female gametes.



An insect pollinating a Flower

By a process called **pollination**, which may require an external agent like **wind, water or insects**, the pollen grains are transferred to the stigma of the flower. From the stigma, the male gametes travel through the style into the ovule and fuse with the female gamete to form the **zygote**. This process is called **fertilisation.**

After fertilisation, the calyx, corolla and stamens wither away i.e., dry up and fall off. The ovary matures to form the **fruit** and the ovules mature into **seeds**. Each seed has the embryonic plant in it. Following a period of rest, under suitable conditions, the seed germinates to form a **seedling**. The seedling grows into a plant, which, in turn, bears root, stem, leaf and flowers and the cycle is repeated.

Annuals, Biennials, Perennials

According to the time taken to complete one life-cycle, plants are classified as annuals, biennials and perennials.

a. **Annuals: Annuals are plants which complete their life-cycles in one season, i.e., they live for only one season.**

   After the seeds are formed, the whole plant, except the seeds, dies.

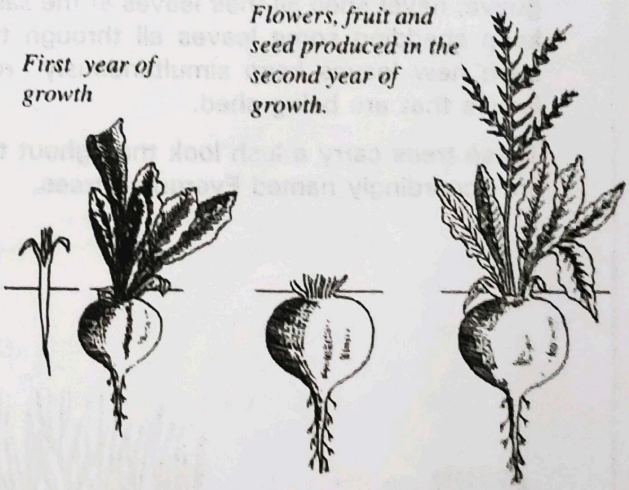
b. **Biennials: Biennials are plants that complete their life cycle in two years.**

   Biennials are generally plants with tap roots which are modified to store food. In their first year of growth from seeds, these plants produce only leaves. Meanwhile, underground they form a food store in the tap root. This is the stage when they are eaten as food by man and animals.

   If the plant is left for another year, it has sufficient reserve food in the root to produce flower and seed, after which it dies.

c. **Perennials:** Perennials are plants which live for more than two years. They flower and produce seeds every year.

Annuals	Biennials
1. Sunflower	1. Carrot
2. Mustard	2. Radish
3. Legumes (pea, bean)	3. Turnip
4. Grasses (rice, maize)	4. Beetroot



Life-history of a Biennial

Example of Perennials		
1. Mango	2. Guava	3. Ginger
4. Dahlia	5. Teak	6. Bamboo
7. Pine	8. Tulip	9. Rose

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Herbs, Shrubs and Trees

Annuals and biennials do not attain great heights and neither do they have strong, sturdy stem. On the other hand, since perennials live for years they grow much in height and possess strong, sturdy, woody stems.

Therefore on the basis of their nature, especially the hardness and height of the stem and duration of life cycle, plants are commonly grouped under herbs, shrubs and trees.

a. **Herbs:** These are small plants characterised by soft, perishable stems. They attain heights upto five feet and are generally annuals and biennials.

b. **Shrubs:** These are woody perennials which may attain a height of ten to fifteen feet. It is characterised by profusely branching stems of nearly the same size just above the ground level, giving the plant a bushy appearance.

c. **Trees:** A tree is a woody perennial. It has a single main stem called trunk which grows for some distance above the ground before giving out a number of woody branches. Palm trees are **conspicuous by the absence of branches.**

Evergreen and Deciduous Trees

1. **Deciduous:** Some trees, like the mulberry and oak, shed all their leaves once a year before winter. Bereft of leaves, the tree carries a skeletal appearance until the new set of leaves appear. Such perennials are called **deciduous** trees.

2. **Evergreen:** Some perennials, like the pine, mango, guava, never shed all their leaves at the same time, but keep shedding some leaves all through the year. As such new leaves keep simultaneously replacing the leaves that are being shed.

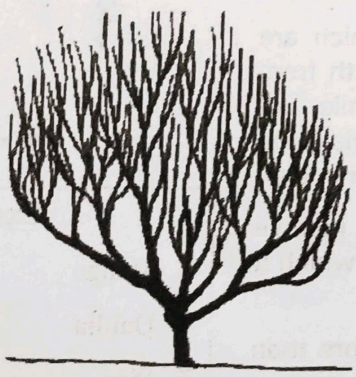
   These trees carry a lush look throughout the year and are accordingly named **Evergreen trees.**

Classification of Plants based on Life Cycle	
Herbs	Annuals and Biennials
Shrubs	Perennials
Trees	Perennials

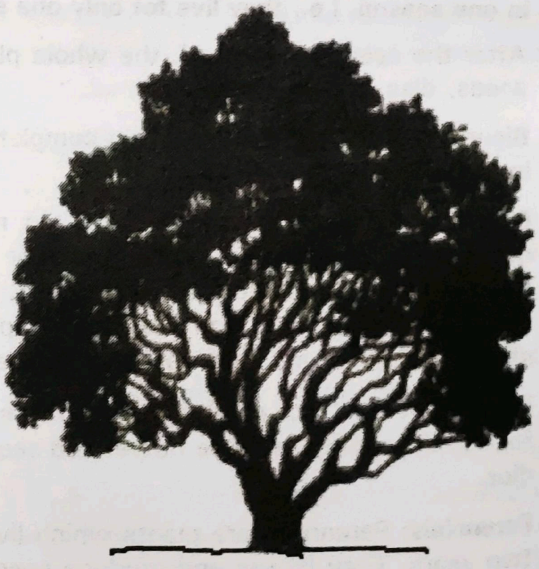
Example of Shrubs		
1. China rose	2. Jasmine	
3. Oleander	4. Garden croton	

Example of Trees		
1. Mango	2. Guava	3. Oak
4. Teak	5. Pine	6. Eucalyptus
7. Tamarind	8. Neem	9. Coconut

Herb



Shrub



Tree

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Exercise

1. Fill in the blanks:

(i) All stems and branches end in a _____.

(ii) _____ bud develops in the axil of the leaf.

(iii) _____ is a part of the stem from which leaves arise.

(iv) _____ is a secondary stem growing from the main stem.

(v) _____ is the region between two successive nodes.

2. Explain, giving a suitable example of each:

(i) Vegetative parts of a plant

(ii) Reproductive parts of a plant

(iii) Annuals

(iv) Biennials

(v) Perennials

(vi) Herbs

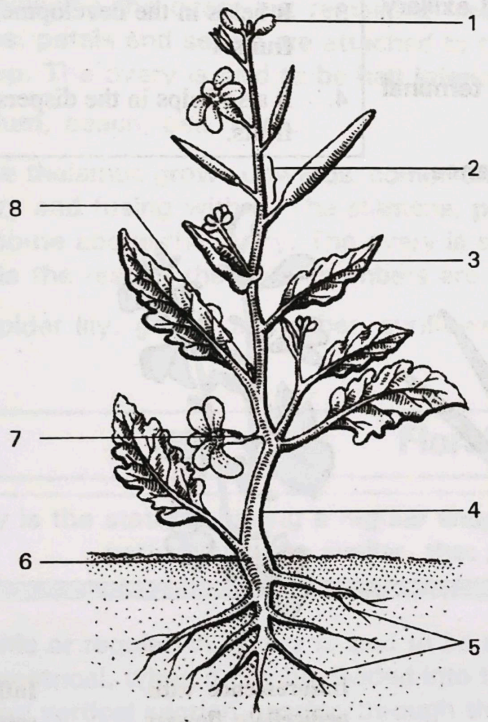
(vii) Shrubs

(viii) Trees

(ix) Evergreen trees

(x) Deciduous trees

3. Label the diagram given below:



(i) Label the parts 1 to 8.

(ii) Is it a dicot or monocot plant? Give one reason.

(iii) Name the vegetative parts of the plant.

4. a. Classify the following as herbs, shrubs or trees:

(i) Mango (ii) Jasmine (iii) Oleander

(iv) Sunflower (v) Rose (vi) Coconut

b. Classify the following as annuals, biennials or perennials:

(i) Tamarind (ii) Carrot (iii) Pea

(iv) Bean (v) Beetroot (vi) Eucalyptus

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5
The Flower

Introduction

A flower is a reproductive part of an angiosperm plant. It is considered to be a modified shoot having nodes and internodes and the leaves are modified into **'floral leaves'**.

In general, flowers are the most attractive part of a plant as their main purpose is to attract birds and insects for **pollination** whereby male gametes are transferred to the female parts of the flower.

Functions of a Flower

1. It helps in the **sexual reproduction** of the plant by producing male gametes (pollen grains) and the female gametes (egg cell). The union of the two gametes results in **fertilisation.**
2. In helps in the process of **pollination,** i.e., transference of pollen grains from the anthers to the stigma of the same or of different flower.
3. It helps in the development of seeds and fruits.
4. It also helps in the dispersal of seeds and fruits.

Flowers are often described on the basis of their position on the stem or branch.

* Flowers that usually grow in the axil of leaves are called **axillary flowers.**
* Flowers borne at the apex of the stem or branch are called **terminal flowers.**

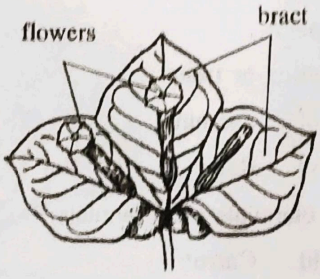
The arrangement of flowers on the stem is called **inflorescence.**

* Flowers that occur singly are called **solitary flowers.**
* The stalk of the individual flower of an inflorescence is called a **pedicel.**
* The flowers with a pedicel are called **pedicellate flowers.**
* **Flowers** which have no stalk are called **sessile flowers.**
* Some flowers grow in clusters. The main axis of an inflorescence is called the **peduncle.**
* In some cases flower is borne in the axil of a special leaf called a **bract.** Bracts may be leaf-like or brightly coloured.
* A leaf or leaf-like structure which may be present on the pedicel is known as **bracteole.**
* Sometimes bracteoles form the outermost whorl of the flower. This is known as the **epicalyx.**
* The fleshy base of a flower to which the different floral parts are attached is known as receptacle or **thalamus.**

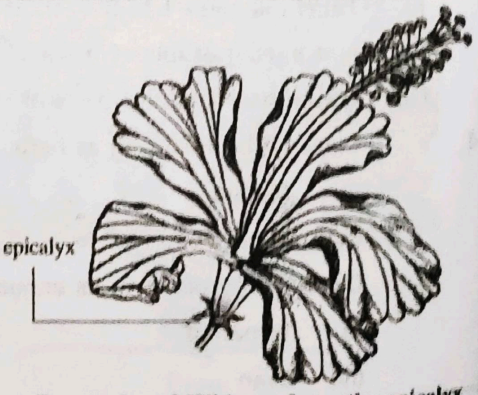
A solitary flower

Inflorescence with pedicellate flowers

Inflorescence with sessile flowers



Flowers of bougainvillea borne in axil of brightly coloured bract



Bracteoles of Hibiscus form the epicalyx

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Position of Floral Leaves on the Thalamus

The parts of a flower are arranged in circles, or spirally on the swollen tip of the pedicel called the **thalamus** or **receptacle**. The **thalamus** represents the axis of the floral whorls.

The thalamus may be flat, convex (dome-shaped) or concave (cup-shaped). The sepals, petals, stamens and ovary occur in a definite sequence on the thalamus. Sometimes, the relative position of the first three whorls in respect to the ovary becomes disturbed due to the unusual growth of the thalamus.

Based on the relative position of the ovary, this gives rise to three kinds of flowers.

1. **Hypogyny:** The thalamus being generally conical or convex, the ovary occupies the highest position on the thalamus. The stamens, petals and sepals are separately and successively inserted below the ovary. The ovary is said to be **superior.**

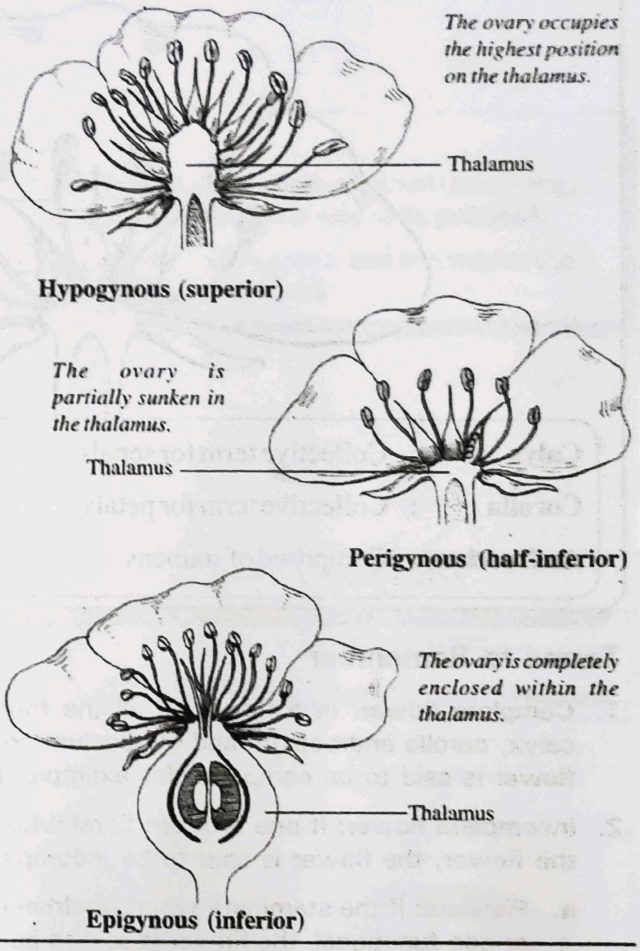
   Example: China-rose, mustard, brinjal

2. **Perigyny:** The thalamus grows to form a cup-shaped structure enclosing the ovary but remaining free from it. The stamens, petals and sepals are attached to the rim of the floral cup. The ovary is said to be **half inferior.**

   Example: Plum, peach, pea, bean.

3. **Epigyny:** The thalamus grows upwards, completely enclosing the ovary and fusing with it. The stamens, petals and sepals are borne above the ovary. The ovary is said to be **inferior** while the rest of the floral members are superior,

   Example: Spider lily, gourd, cucumber, sunflower, apple, pear.



Floral Symmetry

Symmetry is the state of having a **regular shape** such that a line can divide the structure into two equal parts which are similar, that is, the parts are balanced about the line.

1. **Actinomorphic or regular:** A flower is said to be regular or radially symmetrical, when it can be divided into two equal halves by any vertical section passing through the centre. The two halves are mirror images of each other,

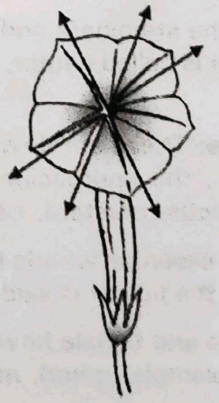
   Example: Mustard, datura, brinjal.

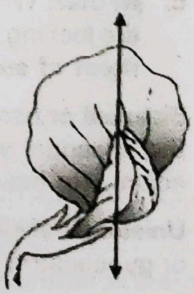
2. **Zygomorphic** (bilaterally symmetrical): When a flower can be divided into two similar halves along only one plane, it is said to be **zygomorphic.**

   Example: Bean, pea, gulmohur.

3. **Asymmetrical or irregular:** In this type, the flower cannot be divided into similar halves along any vertical plane.

   Example: Senna

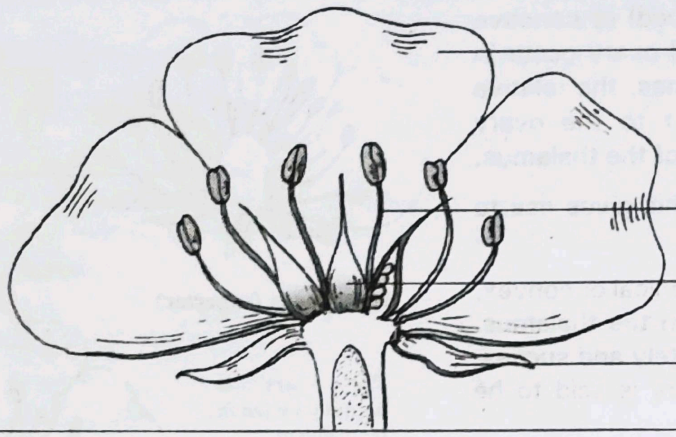

Actinomorphic flower of Petunia


Zygomorphic flower of Pea

Scanned with ACE Scanner

Parts of a Flower

The flower is a specialised shoot of limited growth. It arises in the axil of a leaf, or a leaf-like structure called the **bract.**

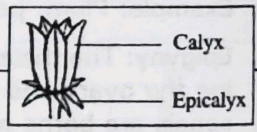


Essential whorls: *Directly concerned with the formation of male and female gametes.*

Calyx	:	Collective term for sepals	**Stamen**	:	Composed of anther and filament
Corolla	:	Collective term for petals	**Gynoecium**	:	Composed of carpels
Androecium	:	Composed of stamens	**Carpel**	:	Composed of ovary, style, stigma

Terms to Remember

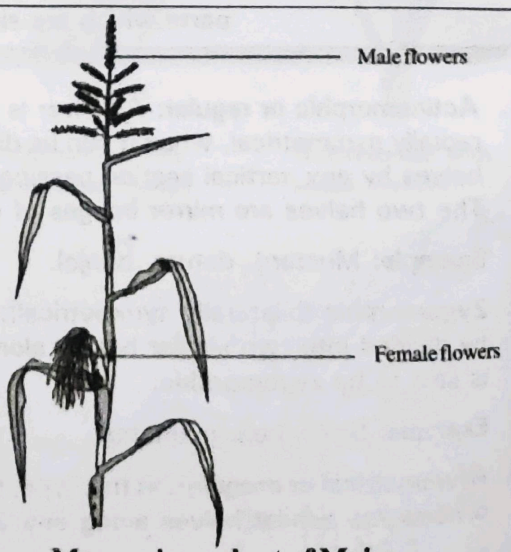
1. **Complete flower:** In a flower, if all the four whorls, i.e., calyx, corolla androecium and gynoecium are present, the flower is said to be complete, for example, ***hibiscus.***
2. **Incomplete flower:** If one or more floral whorl is lacking in the flower, the flower is said to be incomplete.
   a. **Pistillate:** If the staminate whorl (androecium) is absent or non-functional, the flower is said to be pistillate. The non-functional stamens are called **staminodia** as in **orchids** and **canna.**
   b. **Staminate:** In this type of flower, the pistil or carpel (gynoecium) is either totally lacking or non-functional. The non-functional gynoecium is known as **pistillode.**
   c. **Neuter:** When both, the staminate and pistillate whorls are lacking, the flower is called **neuter**, for example, **ray floret of sunflower.**
3. **Bisexual or hermaphrodite:** These are flowers having both, the essential whorls, i.e., the androecium and the gynoecium, for example, **hibiscus, mustard, petunia.**
4. **Unisexual:** If either of the essential whorls (i.e., androecium or gynoecium) is lacking, the flower is said to be unisexual.
   a. **Monoecious:** The male and female flowers are borne on the same plant, for example, **gourd, maize, cucumber.**
   b. **Dioecious:** The male and female flowers are borne on separate plants, for example, **mulberry, palm, papaya.**



Epicalyx

A leaf or leaf-like structure which may be present on the pedicel is known as **bracteole**.

In dicots, there are usually two laterally situated bracteoles, while in monocots there is usually only one. In some flowers, a few bracteoles form the outermost whorl of the flower. This is known as **epicalyx**.

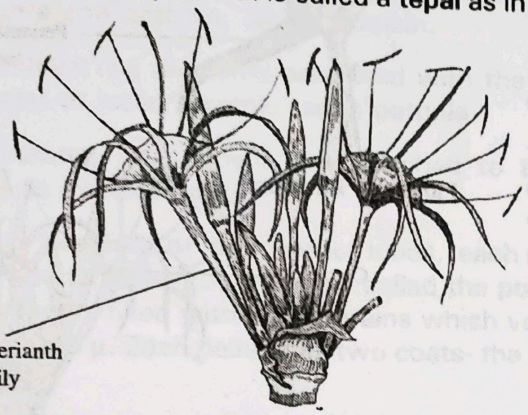


Monoecious plant of Maize

Scanned with ACE Scanner

5. **Naked:** This condition arises when the flower is completely devoid of petals and sepals, for example, **betel.**

6. **Perianth:** When no distinction can be made into petals and sepals, the outer protective whorl is known as a perianth. A single unit of the perianth is called a **tepal** as in spider-lily.



Spider-lily

Note:

1. If the perianth or sepals become coloured (non green) and resemble the corolla it is said to be **petaloid.**
2. If the perianth becomes green and resembles the calyx, it is said to be **sepaloid.**

Function of the Floral Whorls

1. Calyx

The calyx composed of sepals is usually green (sepaloid) and sometimes otherwise coloured (petaloid). It forms the outermost non-essential whorl of the flower and protects the flower in the bud stage. Being green, it also manufactures food by photosynthesis.

The calyx may be:

* **Gamosepalous:** The sepals are more or less united.

  Example: China rose

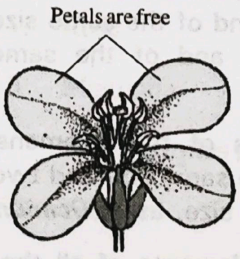
* **Polysepalous:** The sepals are free.

  Example: Mustard

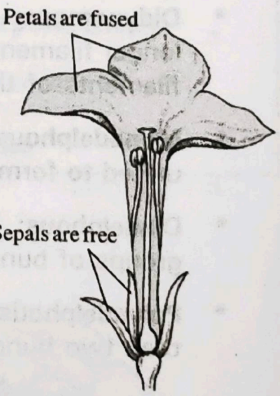
Generally, the calyx withers off when the fruit is formed. Sometimes it remains attached as in tomato and brinjal. Such a calyx is called a **persistent calyx.**

Functions of the Calyx

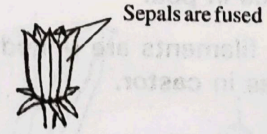
1. Protects the flower in the bud stage.
2. Prepares food for the plant by photosynthesis.



Mustard



Petunia



Hibiscus

2. Corolla

The corolla forms the whorl inner to the calyx. Together with the calyx, it protects the inner essential whorls, the stamens and pistil. The petals of the corolla, like the calyx, may be united to each other or may be free.

* **Gamopetalous:** The petals are united.

  Example: Petunia, disc florets of the sunflower.

* **Polypetalous:** The petals are free.

  Example: China-rose, mustard

The corolla is generally large and showy and assumes various shapes adapted to attract insects and bring about pollination. Some common shapes are cruciform, funnel-shaped, bell-shaped, tubular, papilionaceous, bilabiate, etc.

Functions of the Corolla

1. They attract insects for pollination as they are generally bright and showy.
2. In the bud stage, the corolla together with the calyx, protects the inner essential whorls.

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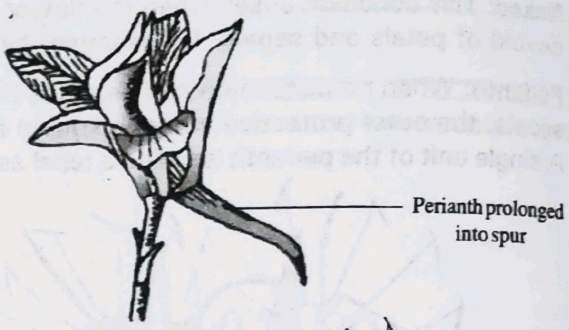
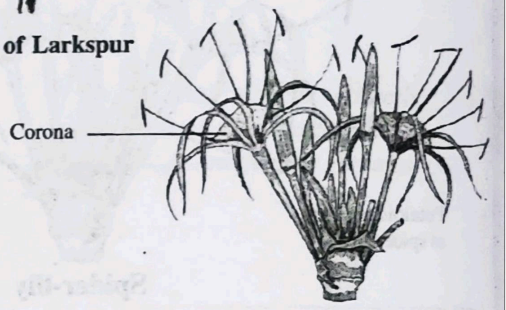
The corolla or perianth may sometimes be provided with outgrowths or appendages such as **spurs, nectaries and corona.**

* **Spurs:** The perianth is prolonged into a tube called **spur** which contains nectar, for example, in balsam, nasturtium, larkspur, orchid.
* **Nectary:** Special glands develop at the base of the flower known as the **nectary**. These secrete nectar.
* **Corona:** Sometimes by a transverse splitting of the corolla, an additional whorl may be formed. This may consist of lobes, scales or hair and is known as the **corona**. The corona adds to the beauty of the flower and is thus an adaptation to attract insects for pollination, for example, in oleander, daffodil, passion flower.



Flower of Larkspur

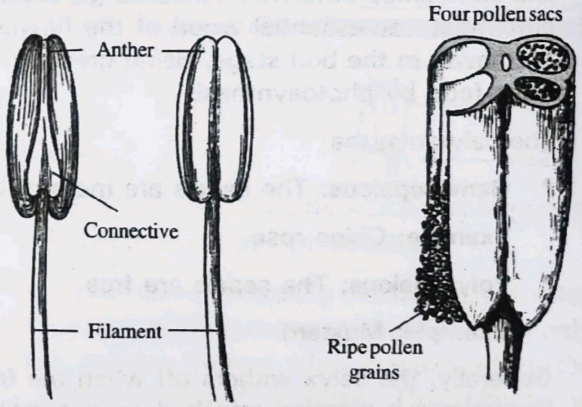


Flower of Spider lily

3. Androecium

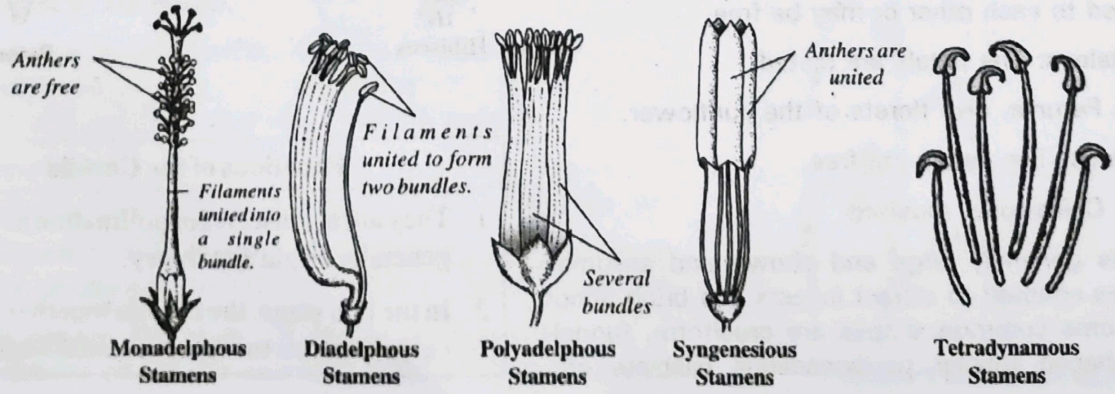
The androecium is the **male reproductive** whorl of a flower, inner to the corolla. It is composed of a number of **stamens**, each of which consists of a filament, anther and connective. The filaments may be free from each other and other structures or they may be fused with each other or fused with the petals or gynoecium. They may also vary in size.

* **Polyandrous:** All the stamens are free and their filaments may be of the same or different sizes.
* **Tetradynamous:** Consists of six filaments. Two of the filaments are longer and of the same size. Four of the filaments are smaller and of the same size, as in **mustard.**
* **Didynamous:** Consists of four stamens - two with longer filaments of the same size and two with shorter filaments of the same size, as in ***Ocimum.***
* **Monadelphous:** The filaments of all the stamens are united to form a single staminal tube, as in **china-rose.**
* **Diadelphous:** The filaments are united to form two groups of bundles, as in **pea.**
* **Polyadelphous:** The filaments are united to form more than two bundles, as in **castor.**



Dorsal view **Ventral view** **Stamen dehiscing on one side**

Parts of a Stamen



Monadelphous Stamens **Diadelphous Stamens** **Polyadelphous Stamens** **Syngenesious Stamens** **Tetradynamous Stamens**

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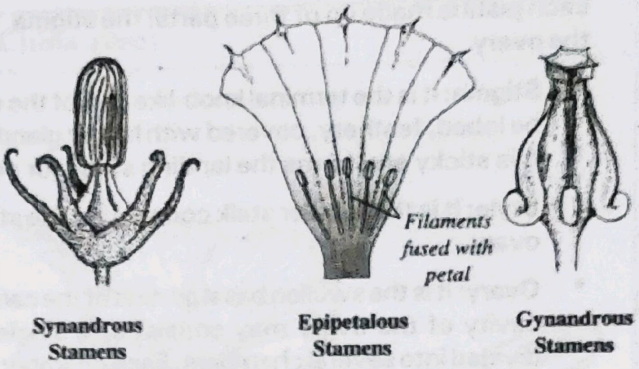
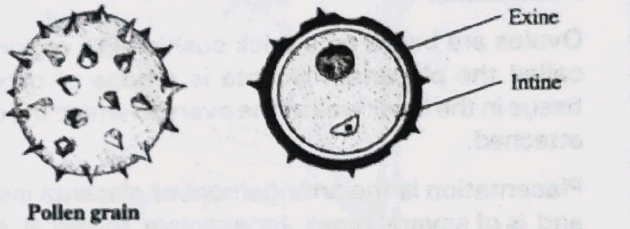
- **Syngenesious**:The filaments are free from each other but the anthers are closely arranged to form a cylindrical tube around the style, as in **sunflower**.
- **Synandrous**:The stamens are united both by their filaments and anthers, as in **pumpkin**.
- **Epipetalous**:The filaments are fused with the petals to a greater or lesser extent, as in **petunia**.
- **Gynandrous**:The stamens are attached to the gynoecium as in **calotropis**.



The anther consists of two anther-lobes, each of which generally has two chambers (loculi) called the **pollen sacs**. Each chamber is filled with pollen grains which vary in size from 10 to 200 μ. Each pollen has two coats- the exine and the intine.

- **Exine:** This is the tough, cutinised outer protective coat. It is often provided with spiny outgrowths or a rough surface as an adaptation for pollination.
- **Intine:** It is a thin delicate cellulose layer lying internal to the exine. It is the intine that grows into the pollen tube.



4. Gynoecium

The gynoecium or pistil is the female reproductive part of the flower and forms the innermost whorl. The pistil is composed of one or more carpels. If it is made up of more than one carpel, the carpels may be free or united together.

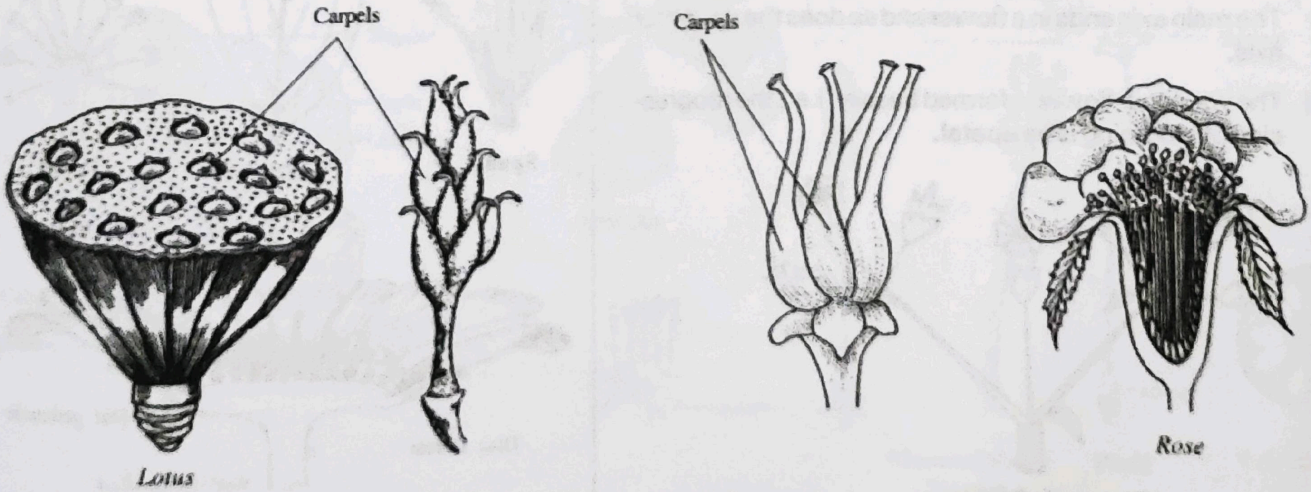
- **Apocarpous:** The gynoecium consists of more than one carpel and the carpels are free, i.e., each forms a separate ovary, style and stigma.
- **Syncarpous:** The gynoecium consists of more than one carpel and the different carpels are united to form a **single** ovary, a single style and often even a single stigma.

Examples of Apocarpous Ovary

1. Rose	2. Lotus
3. Magnolia	4. Michelia (*Champa*)

Examples of Syncarpous Ovary

1. Mustard	2. Hibiscus
3. Cotton	4. Liliies



Apocarpous Ovary

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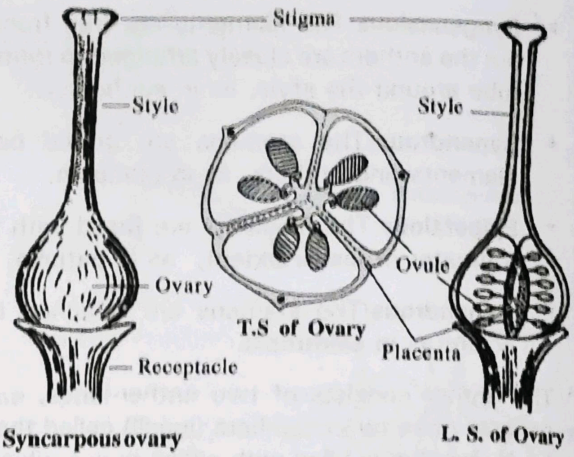
Each pistil is made up of three parts: the **stigma**, the **style** and the **ovary**.

* **Stigma:** It is the terminal knob-like part of the carpel. It may be lobed, feathery, covered with hair or glandular papillae. It is sticky and forms the landing stage for pollen grains.
* **Style:** It is the tubular stalk connecting the stigma and the ovary.
* **Ovary:** It is the swollen basal portion of the carpel. The inner cavity of the ovary may consist of a single chamber or divided into several chambers. Each chamber contains one or more rounded, egg-like bodies which are the rudiments of seeds. These are known as **ovules**. Each ovule encloses a large oval cell called the **embryo-sac**.

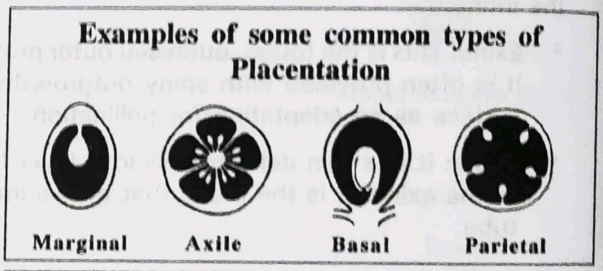


Parts of the Gynoecium

Placentation

Ovules are borne on a thick cushion-like region in the ovary called the **placenta**.Placenta is a ridge of parenchymatous tissue in the inner wall of the ovary to which the ovules remain attached.

Placentation is the arrangement of placenta inside the ovary and is of several types, for example, marginal, axile, parietal, central, free-central, basal and superficial.

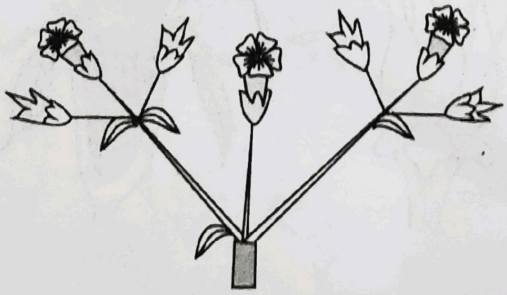


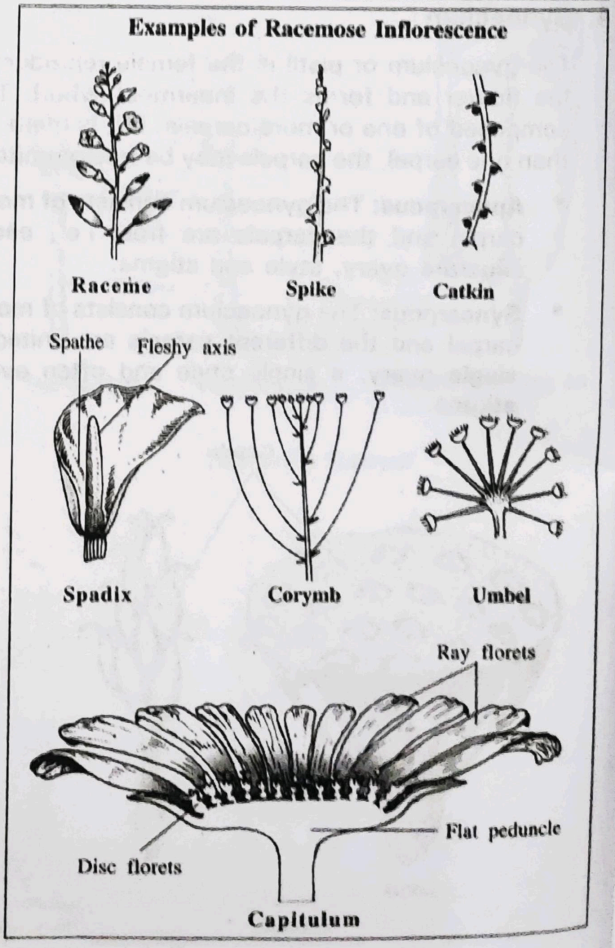
Inflorescence

The arrangement of flowers on a twig is called **inflorescence.**

Two main types of inflorescence are recognised - **Racemose** and **Cymose.**

1. **Racemose:**
   (i) The main axis never ends in a flower and continues to grow.
   (ii) Lateral flowers are formed in **acropetal succession**, i.e., youngest flower is produced apically and older basally.
2. **Cymose:**
   (i) The main axis ends in a flower and so does the daughter axis.
   (ii) The youngest flower is formed basally, i.e., the progression of blooming is **basipetal.**


Cymose Inflorescence



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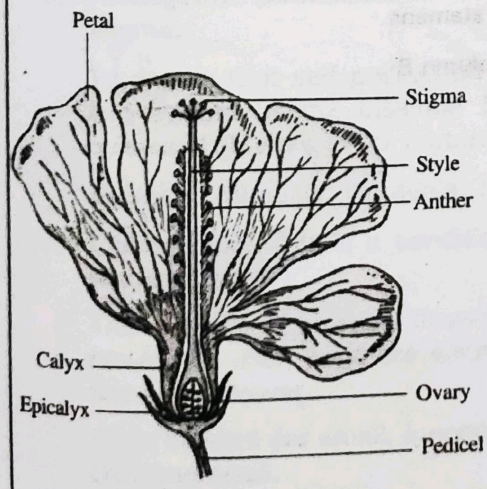
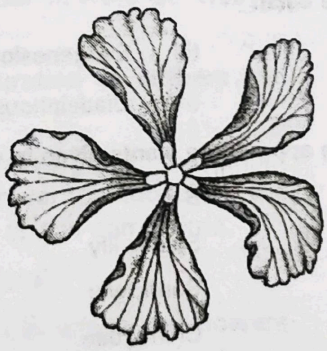
Hibiscus rosa-sinensis (China rose)

Family	Malvaceae
Habit	Shrub
Root	Tap root
Stem	Erect, strongly fibrous and mucilaginous.
Leaf	Simple, alternate, stipulate.
	Multicostate reticulate venation.
Inflorescence	Cymose: solitary terminal.
Flower	Bracteoles form calyx-like structure called epicalyx.
	Complete, actinomorphic, hypogynous.
Calyx	5 sepals: gamosepalous. Covered with stellate hairs.
Corolla	5 petals: polypetalous. Large red/pink petals.
Androecium	Nectar secreted in pits in the base of the petals.
	Numerous stamens, united - monadelphous, epipetalous.
	Upper part of the filament bearing anthers are free.
Gynoecium	5 carpels, syncarpous, Superior ovary.
	Axile placentation.
Fruit	Simple, dry, capsule.
Seed	Endospermic.
Pollination	Cross pollination. Insects attracted by nectar and gaudy corolla.

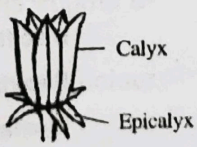
A Flower of Hibiscus *rosa-sinensis*

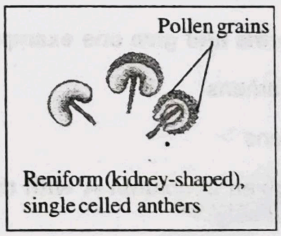


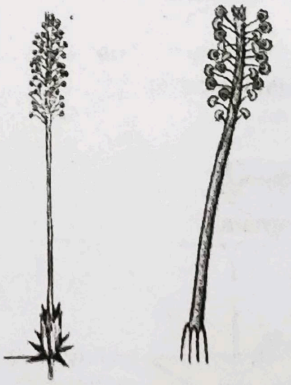
L.S. of Flower



Corolla

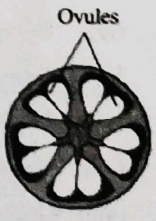






Monadelphous Stamen

Pistil



T.S. of Ovary

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Exercise 1

1. Give one term for the following:

(i) Flowers that occur singly.

(ii) Stalk of the individual flower of an inflorescence.

(iii) Flowers which have no stalk.

(iv) The main axis of an inflorescence.

(v) Bracteoles forming the outermost whorl of a flower.

(vi) The base or receptacle of a flower.

(vii) A flower in which all the four whorls are present.

(viii) A non functional gynoecium.

(ix) Flowers having both the essential whorls.

(x) A flower in which both, the gynoecium and androecium are absent.

(xi) The male and female flowers are borne on the same plant.

(xii) The male and female flower are borne on separate plants.

(xiii) The flower is completely devoid of petals and sepals.

(xiv) Petals and sepals are fused to form a single unit.

2. Explain the following terms:

(i) Petaloid (ii) Actinomorphic (iii) Zygomorphic

(iv) Perigynous (v) Epigynous (vi) Gamosepalous

3. State the functions of each:

(i) Calyx (ii) Corolla

4. Give two examples of each:

(i) Gamopetalous flower (ii) Polypetalous flower

5. Explain the following terms and give one example each:

(i) Monadelphous stamens (ii) Syngenesious stamens

(iii) Epipetalous stamens (iv) Diadelphous stamens

6. Match the description given in column A with the appropriate plants given in column B

A	B
(i) Capitulum	Spider lily
(ii) Monadelphous stamens	Sunflower
(iii) Perianth	China rose
(iv) Syngenesious anthers	Petunia
(v) Tetradynamous anthers	Ray floret
(vi) Persistent calyx	Disc floret
(vii) Neuter flower	Racemose
(viii) Umbel	Mustard

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Pollination

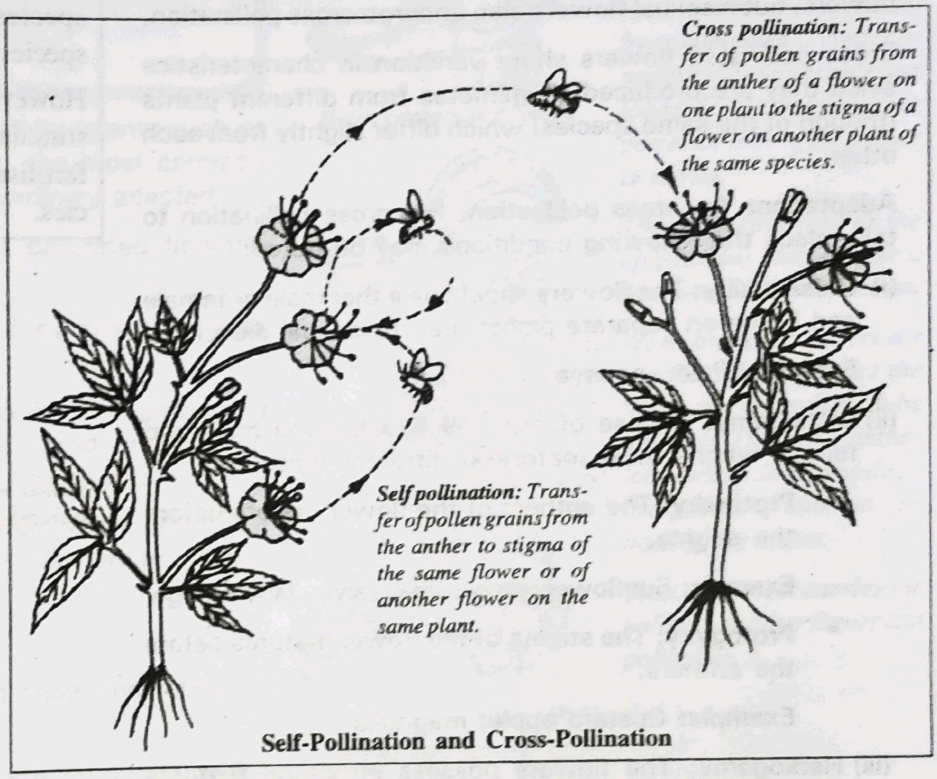
Pollination is the transference of pollen grains from the anther of a flower to the stigma of a flower.

As explained earlier, the flower is the part of the plant that brings about reproduction by sexual means.

The androecium and the gynoecium produce the male and female gametes respectively, which on fusion, form the zygote.

The fusion of the male and female gametes is termed as **fertilisation**. In order to bring about fertilisation, the most important step is to bring the two gametes together. This is brought about by a process called **pollination**.

Pollination is of two kinds-**self pollination** and **cross pollination**.



Self-Pollination and Cross-Pollination

1. Self Pollination

In self pollination, the pollen produced by the anther of a flower is transferred to the stigma of the same flower or to the stigma of another flower borne on the same plant.

Self pollinated flowers bear similar genetic characters.

Adaptations for Self Pollination

Self pollination can occur in bisexual flowers as well as monoecious unisexual flowers.

(i) **Homogamy: Simultaneous maturation of anthers and stigma.**

To ensure that self pollination takes place, the anther and stigma of the bisexual flower or those of the unisexual flowers must mature at the same time.

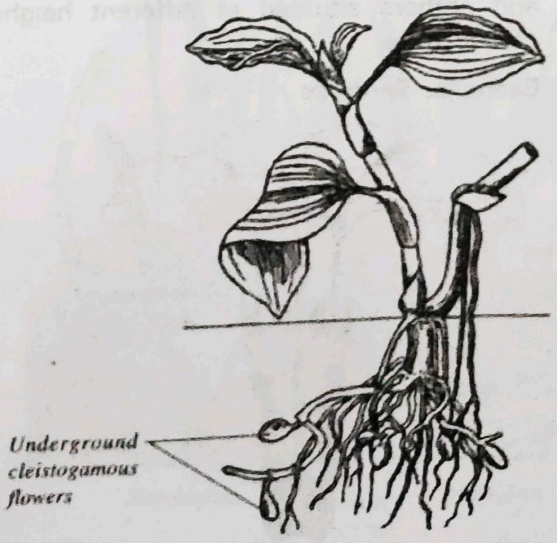
Example: Mirabilis, Gardenia, Ixora

(ii) **Cleistogamy: This is a condition in which the flowers remain closed.**

There are some bisexual flowers that never open. As a result, the ollen grain are distributed on the stigma of the same flower.

Such flowers are small, inconspicuous and lack colour and fragrance.

Example: Flowers of Commelina and groundnut borne on underground branches, balsam, sundew, wood-sorrel.



Cleistogamy in Commelina

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2. Cross Pollination

Cross pollination is the transfer of pollen grains from the anthers of flowers of one plant to the stigma of a flower of another plant. As a rule, cross pollination occurs in unisexual flowers, but bisexual flowers also undergo cross pollination.

Cross pollinated flowers show variation in characteristics since they are produced by gametes from different plants (though of the same species) which differ slightly from each other.

Adaptations for cross pollination: For cross pollination to take place the following conditions may be noted:

(i) **Unisexuality:** The flowers should be either male or female and borne on separate plants, i.e., unisexual dioecious.

Example: Palm, papaya

(ii) **Dichogamy:** In case of bisexual flowers, the male and female whorls must mature at different times.

* **Protandry:** The anthers of the flower mature before the stigma.

Example: Sunflower, sweat pea, salvia, lady's finger

* **Protogyny:** The stigma of the flower matures before the anthers.

Example: Custard apple, magnolia

(iii) **Herkogamy:** The flowers possess structural features which do not allow self pollination.

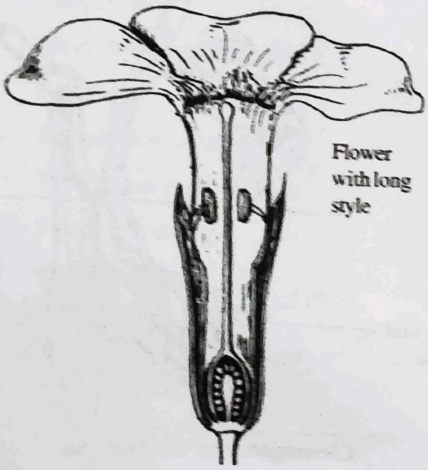
Example: In pansy, a hood covers the stigma.

(iv) **Self sterility:** The pollen from the anther fail to germinate on the stigma of the flower.

Example: Orchids

(v) **Heterostyly:** Flowers have styles of different lengths and anthers situated at different heights upon the corolla tube.

Example: Primrose

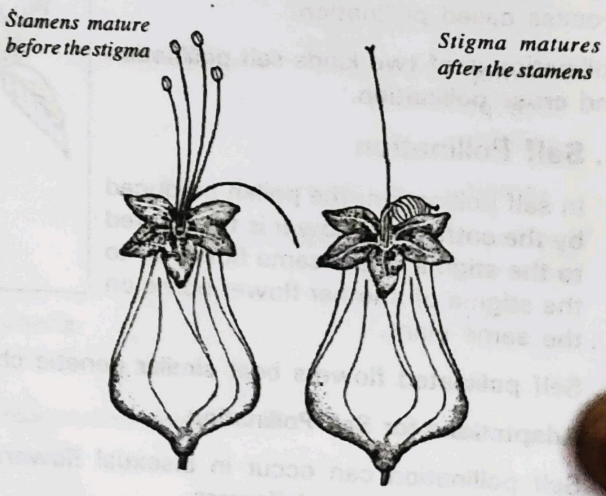


Heterostyly in Primrose

Incompatibility

In cross pollinated plants, the pollen from a certain species often reaches the stigma of a different species.

However, the chemicals present in the stigma fail to stimulate the growth of the pollen tube and hence no fertilisation occurs between plants of different species.



Protandrous Flowers of *Clerodendron*

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Agents of Cross Pollination

Entomophilous	:	Insect pollinated
Anemophilous	:	Wind pollinated
Hydrophilous	:	Water pollinated
Ornithophilous	:	Bird pollinated

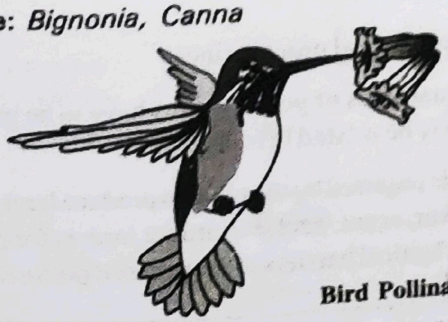
Cross pollination is generally brought about by agents such as wind, water, insects, birds, and animals, the most common being wind and insects. Flowers are accordingly adapted.

1. **Entomophilous:** Plants are the insect pollinated flowers. They are of two main types:
   - **Nectar flowers:** These are visited by the pollinating insects for nectar.
   - **Pollen flowers:** These are visited by the pollinating insects for pollen grains which are produced in large quantities and offered as food to the insects.
2. **Anemophilous:** Plants or wind pollinated plants often produce pollen grains that are provided with wings. These facilitate distribution by wind,

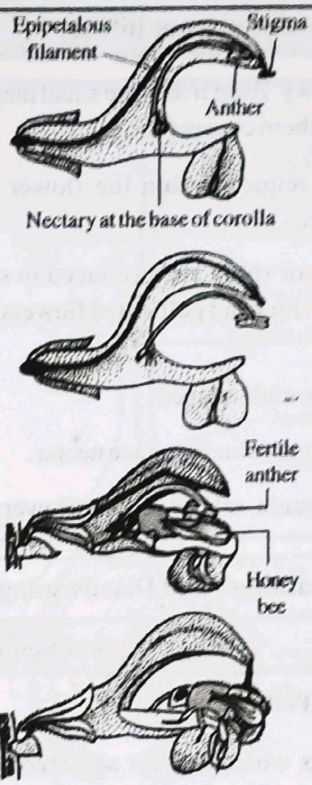
   Example: Pine, Maize
3. **Hydrophilous:** Plants are aquatic and show the following characteristics:
   (i) Large quantities of pollen grain are produced which often have the same specific gravity as that of water. This enables it to float on water.
   (ii) In some cases, the male flowers float on the water surface till they meet female flowers.
   (iii) Flowers are small, inconspicuous and dioecious.

   Example: *Vallisneria, Hydrilla*
4. **Ornithophilous** plants show the following adaptations
   (i) They produce plenty of nectar which is contained in modified pitcher-shaped nectaries.
   (ii) Usually scentless, as birds lack a good sense of smell.
   (iii) Flowers are coloured, especially red and orange since birds are highly sensitive to these colours.

   Example: *Bignonia, Canna*



Bird Pollinating a Flower



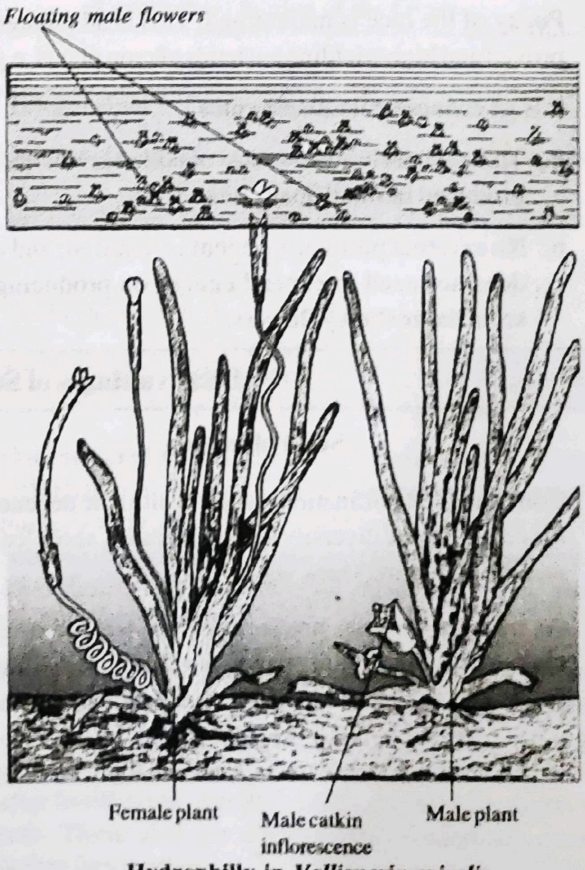
The two anther lobes of the two stamens are separated by an elongated curved connective. The upper anterior lobe is fertile and the lower posterior lobe of the anther is sterile.

The connective rests on the epipetalous filament like a sea-saw plank on a fulcrum.

When the insect enters the corolla tube it pushes the lower sterile anther lobe upwards. The fertile anther lobe swings down and dusts the pollen grains on the back of the insect.

Thus, the insect carries the pollen to another flower and pollinates it.

Insect Pollination in *Salvia*



Hydrophilly in *Vallisneria spiralis*

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Comparison of Insect and Wind Pollinated Flowers

Insect Pollinated (Entomophilous)	Wind Pollinated (Anemophilous)
1. Flowers are large and showy. Even if they are small they occur in clusters, which make them conspicuous.	Small inconspicuous flowers, usually not coloured and are often green.
2. Anthers are small and remain within the flower firmly attached to their filament.	Anthers are large, protrude out of the flowers and are loosely attached to the filament so that they are easily moved by wind.
3. Pollen grains are sticky or spiny and produced in smaller quantities as compared with wind pollinated flowers.	Pollen grains are smooth and light so that they can be easily carried by the wind. Produced in very large quantities to compensate loss in transit.
4. Stigmas are sticky, flat or club-shaped.	Stigmas are large, feathery and hang out of the flower.
5. Flowers are generally scented and produce nectar.	Flowers are not scented and do not produce nectar.
6. *Example:* china rose, petunia, salvia, pea, sunflower.	*Example:* Paddy plants like maize, rice, wheat, palms, pine.

Advantages and Disadvantages of Self Pollination and Cross Pollination

Advantages of Self Pollination and Cross Pollination

Self Pollination	Cross Pollination
1. In homogamous flowers which are not self-sterile, self-pollination is a surer method.	Results in much healthier offsprings which are better adapted to their environment.
2. Purity of the race is maintained. This is advantageous improved and high-yielding varieties of crop plants, e.g. wheat.	New varieties are produced by cross pollinating different varieties of the same species or even different species (hybrids).
3. It is an economical process since a. There is hardly any wastage of pollen grains and they are produced in small quantities. b. No external pollinating agent is required, and the plant does not need to expend energy on producing nectar, scent, large showy flowers.	The seeds produced are abundant and viable. The genetic diversity associated with cross pollination, increase the pace of evolution besides hybrid vigour of seed germination.

Disadvantages of Self Pollination and Cross Pollination

Self Pollination	Cross Pollination
1. Continued self pollination results in ultimate degeneration of the race. Genetic diversity is not generated, seeds lose vitality and the off-springs lack vigour.	Cross pollination is not always certain since there is dependence on external pollinating agents.
2. As no new varieties are formed, the weaker or defective characters of the variety cannot be eliminated. Thus there is little or no chance for improvement in the next generation.	It is an uneconomical process since a. Large quantities of pollen grains have to be produced as much may be wasted in transit. b. Energy is required by the plant to produce large conspicuous flower, scent, nectar to attract insects for pollination and mechanical barriers to prevent self pollination.

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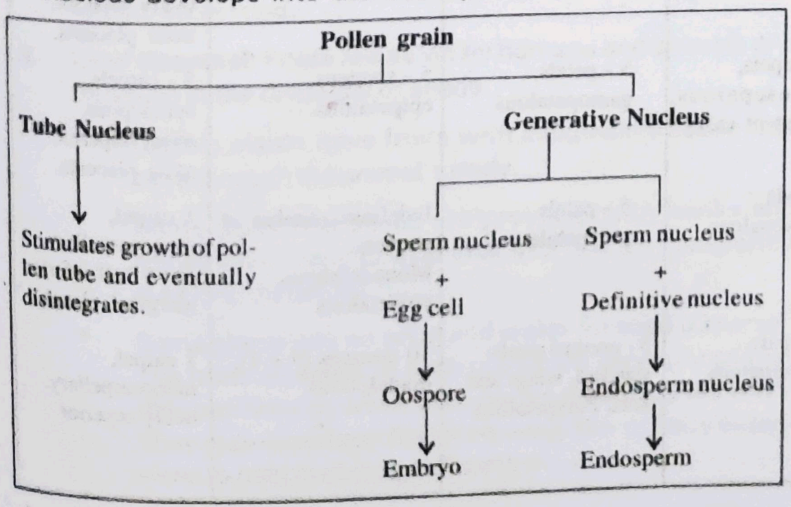
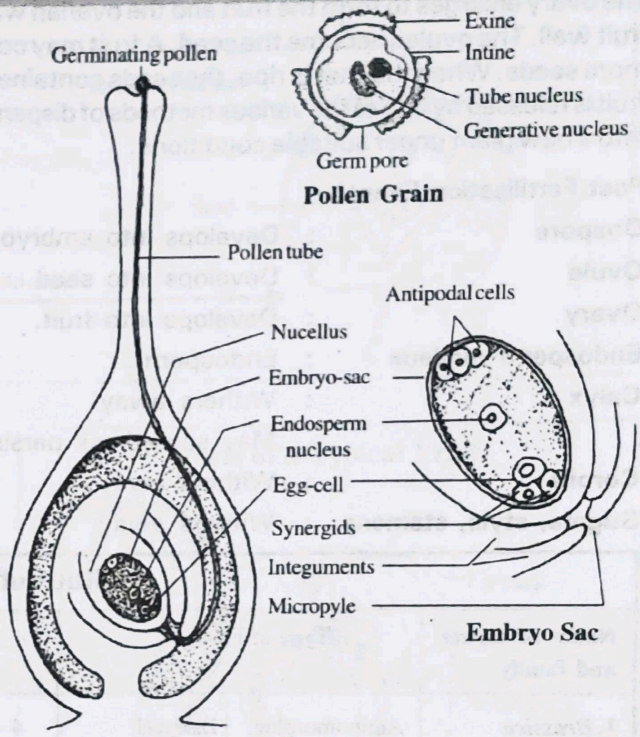
Fertilisation

Fertilisation is the fusion of the nuclei of male and female gametes to form à zygote.

Successful pollination is followed by fertilisation.

1. The pollen grain on reaching the stigma absorb nutrients secreted by the stigma and the pollen tube begins to grow.
2. The inner coat of the pollen grain, called **intine,** through some weak spot in the outer coat **exine,** grows into the tube and passes through the style by dissolving the tissues with the help of enzymes. The nucleus of the mature pollen grain has already divided into two nuclei at the time of pollination. The two nuclei are the **tube nucleus** and the **generative nucleus.**
3. The **tube nucleus** remains close to the growing tip of the pollen tube and eventually disintegrates.
4. Meanwhile, the **generative nucleus** divides into two male gametes or nuclei which move to the tip of the tube and lie in the mass of cytoplasm.
5. The tube then turns towards the micropyle, passes inwards through it, and finally reaches the embryo sac, close to the egg cell.
6. After the pollen tube penetrates into the embryo sac, the tip of the tube dissolves and the male gametes are set free inside the ovule.
7. One male gamete fuses with the egg cell and forms the fertilised egg or the **zygote.**
8. The second male gamete fuses with the secondary nucleus (definitive nucleus), i.e., the nucleus formed by the fusion of the polar nuclei and forms the **endosperm nucleus. The** fusion of male gamete with the two polar nuclei is often termed as **triple fusion.**
9. The zygote develops into the **embryo,** while the endosperm nucleus develops into the **endosperm** of the seed.





Longitudinal Section of the Ovary

Parts of a Mature Ovule

Integuments : Two layers of protective coating.

Micropyle : Minute pore or opening through which the pollen tube enters.

Nucellus : Nutritive tissue lining the interior of the ovule.

Embryo sac : In the centre of the nucellus, it contains the egg cell, antipodal cells and polar nuclei (definitive). Synergids are the cells flanking the egg cell.

Double Fertilisation: In flowering plants, two sets of fertilisation takes place. One occurs between the sperm, nucleus and the egg cell, while the other takes place between the second sperm cell and the definitive nucleus. Thus, fertilisation in flowering plants is referred to as **double fertilisation.**

If, for some reason, the egg cell fails to fertilise, the synergids (also called help cells) assume the role of the egg cell. In case fertilisation occurs between the egg cell and male nuclei, the synergids disintegrate soon after fertilisation. Antipodal cells also have no positive role. These also get disorganised, sometimes even before fertilisation.

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Post Fertilisation

After fertilisation, the egg cell surrounds itself with a cell wall and is known as the **oospore**.

The ovary enlarges to form the fruit and the ovarian wall forms the fruit wall. The ovules become the seed. A fruit may contain one or more seeds. When the fruit is ripe, the seeds contained within the fruit is released by one of the various methods of dispersal and grow into a new plant under suitable conditions.

Post Fertilisation Events

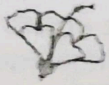
Oospore	:	Develops into embryo.
Ovule	:	Develops into seed.
Ovary	:	Develops into fruit.
Endosperm nucleus	:	Endosperm.
Calyx	:	Withers away. May sometimes persist.
Corolla	:	Withers away
Stigma, style, stamens	:	Withers away

Artificial Pollination

Artificial pollination is the practice adopted by the scientists to evolve new varieties of plants.

The anthers of young flowers are removed and the flowers are covered by plastic bags. These flowers are then pollinated with the pollen from plants of the desired variety.

A Study of some common Flowers

Name of flower and family	Type of Flower		Calyx	Corolla	Androecium	Gynoecium
1. *Brassica* (Mustard) Cruciferae	Actinomorphic	Bisexual, hypogynous	4 - sepals, polysepalous	4 - petals, polypetalous	6 - stamens, (2 + 4) free tetradynamous.	2 - carpels, syncarpous, ovary superior, parietal placenta
2. *Helianthus* (Sunflower) Compositae						2 - carpels, syncarpous, ovary inferior, basal placenta
a. Disc floret	Actinomorphic	Bisexual, epigynous	Scaly	5 - petals, gamopetalous	5 - stamens, epipetalous, syngenesious anthers.	
b. Ray floret	Zygomorphic	Neuter (or female)	Pappus, or absent	Single, large, yellow petal		2 - carpels, syncarpous, ovary superior, axile placenta.
3. *Petunia* Solanaceae	Actinomorphic	Bisexual, hypogynous	5 - sepals, gamosepalous, persistent calyx	5 - petals, gamopetalous	5 - stamens, epipetalous	5 - carpels, syncarpous, ovary superior, axile placenta.
4. *Hibiscus rosa-sinesis* (China rose) Malvaceae	Actinomorphic 	Bisexual, hypogynous epicalyx present	5-sepals gamosepalous	5 - petals polypetalous	Indefinite number of stamens. Monadelphous, epipetalous	1 carpel, monocarpellary, ovary half inferior marginal placenta
5. *Pisum sativum* (Pea) Papilionaceae	Zygomorphic	Bisexual Perigynous	5 - sepals gamosepalous	5 - unequal petals: standard, wings and keel. Polypetalous	10 stamens (9 + 1), diadelphous.	1 carpel, monocarpellary, ovary superior

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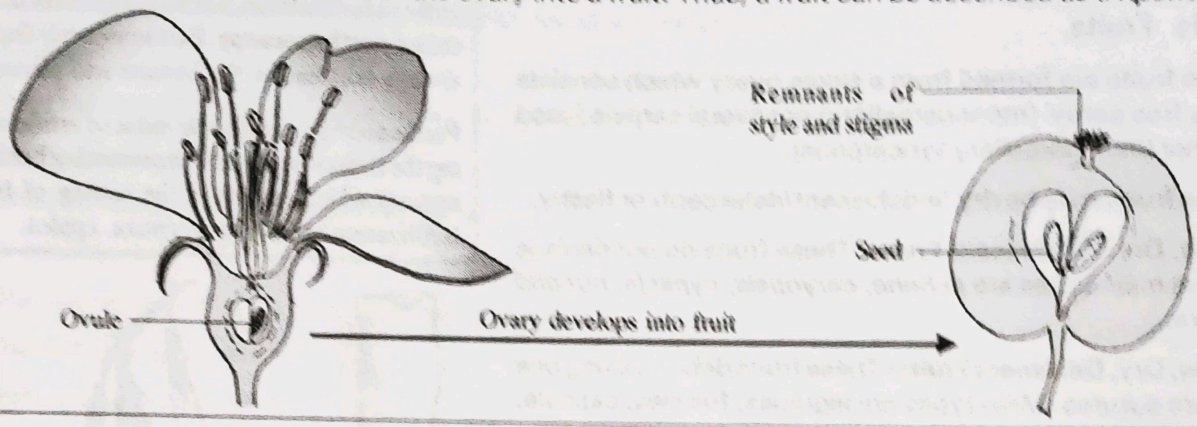
Fruit and Seed

Fertilization results in the development of the ovary into a fruit. Thus, a fruit can be described as a **ripened ovary**.



Parts of a Fruit

A typical fruit consists of the **pericarp** and the **seed**. The **pericarp** or **fruit wall** develops from the ovary wall. It is generally differentiated into **three** layers:

a. **Epicarp:** Forms the outermost layer.

b. **Mesocarp:** It is the middle layer.

c. **Endocarp:** Forms the innermost layer.

Functions of the Fruit

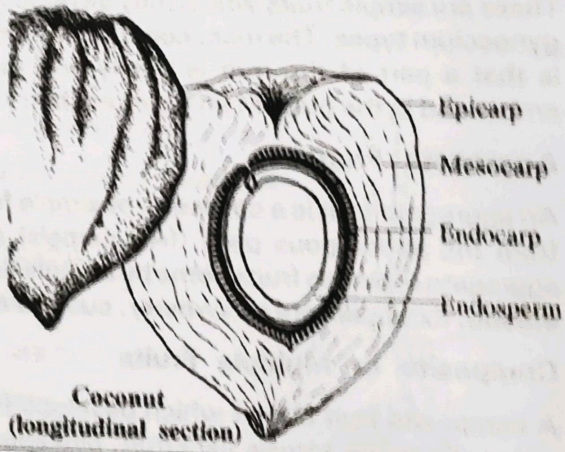
1. **Protection:** The fruit encloses the seeds and thus protects them from injury and effects of unfavourable climatic conditions.

2. **Source of food:** Certain fruits like mango, apple, chickoo and tomato store food.

3. **Seed dispersal:** Fruits are eaten by humans and animals and thus help in the dispersal of seeds.

   * Certain plants have fruits with indigestible seeds that pass through the animal's body.
   * Some fruits and seeds are provided with **hooks** and **spines** which cling to an animal's fur and are transported over long distances.
   * Some plants rely on **wind** and **water** for seed dispersal. The fruits or seeds of such plants are very light so that they can float on water or be blown around by the wind. They may even bear flattened wing-like or hairy extensions to help in gliding or flotation.

Parts of a Typical Fruit



Seeds develop from the fertilised ovule.

Modes of dispersal

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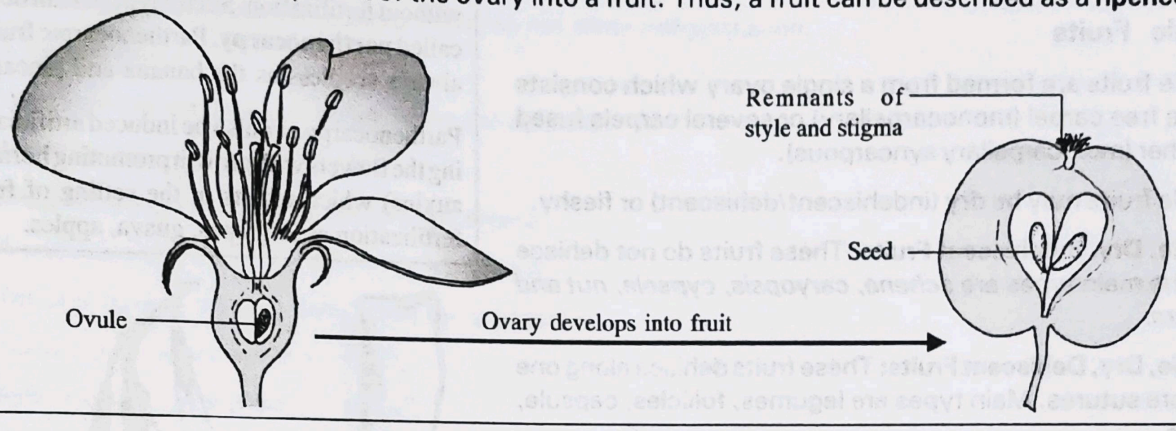

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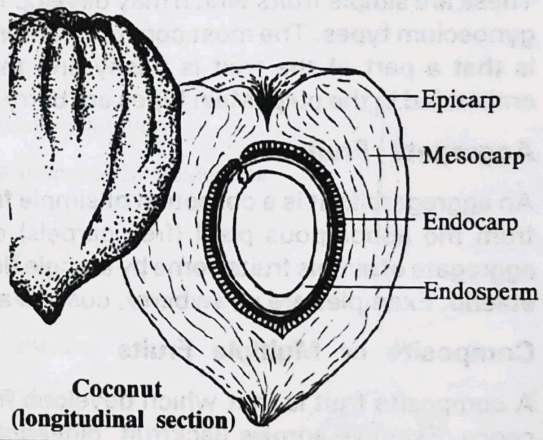
Parts of a Typical Fruit



Coconut (longitudinal section)

Functions of the Fruit

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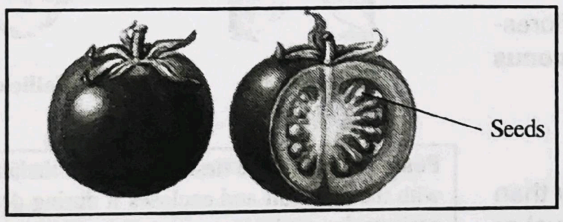

Seeds develop from the fertilised ovule.

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Modes of dispersal

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It may be noted that many of the so called 'vegetables' like brinjals, tomato, lady's finger, cucumber, peas, beans etc., are in the true botanical sense, fruits.

A. Simple Fruits

Simple fruits are formed from a single ovary which consists of one free carpel (monocarpellary) or several carpels fused together (multicarpellary syncarpous).

Simple fruits may be dry (indehiscent/dehiscent) or fleshy.

Simple, Dry, Indehiscent Fruits: These fruits do not dehisce and the main types are *achene, caryopsis, cypsela, nut and samara.*

Simple, Dry, Dehiscent Fruits: These fruits dehisce along one or more sutures. Main types are legumes, follicles, capsule, siliqua

Simple Fleshy Fruits

These are simple fruits which may develop from a variety of gynoecium types. The most constant feature of these fruits is that a part of the fruit is fleshy and the seeds remain embedded in the pulp. Main types are berry and drupe.

B. Aggregate Fruits

An aggregate fruit is a collection of simple fruits developing from the apocarpous pistil (free carpels) of a flower. An aggregate of simple fruits borne by a single flower is called an **etaerio**. Examples are strawberry, custard apple, lotus.

C. Composite or Multiple Fruits

A composite fruit is that which develops from an inflorescence. Example **sorosis** (jackfruit, pineapple) and **syconus** (fig,banyan).

D. False Fruit

A false fruit develops from any part of the flower other than the ovary. It may develop from the receptacle (thalamus) or the calyx. Example, **pome.**

Parthenocarpy

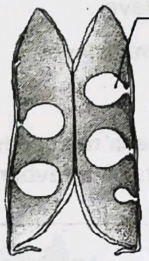
Sometimes the ovary develops normally into a fruit without fertilization. Such a type of fruit development is called **parthenocarpy.** Parthenocarpic fruits are almost always seedless as the banana and pineapple.

Parthenocarpy can also be induced artificially by spraying the flowers with growth promoting hormones (called auxins) which results in the setting of fruits without fertilization as in grapes, guava, apples.

Caryopsis: Maize

Samara: Ash

Nut: Cashew

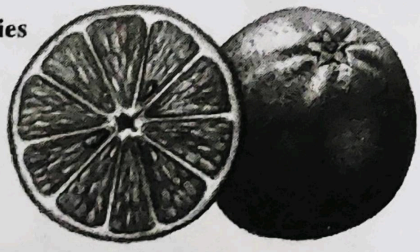


Legume : Pea

Follicle : Madar

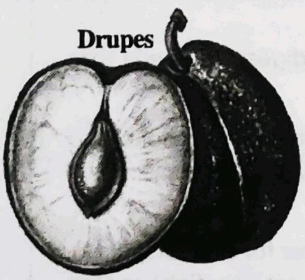
Pome : In pome, the fleshy part is the thalamus which fuses with the real fruit and encloses it during development. The pericarp is cartilaginous and discarded during eating, e.g., apple, pear.

Types of Fruits



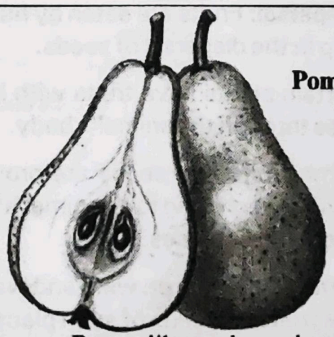
Berries like Oranges, lemons, tomatoes.

Seeds are enclosed in soft pulp.



Drupes like plum, mango, coconut.

The stony seed is in the middle of the fleshy fruit.



Pomes like apples and pears.

The seeds are pips in a core formed from the carpel of the flower.

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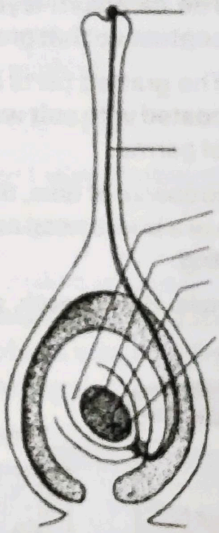
Exercise 2

1. **Give one name for the following:**
   - (i) Flowers possess structural features which do not allow self-pollination.
   - (ii) A ripened ovary.
   - (iii) The stigma of the flower matures before the stamens.
   - (iv) Arrangement of flowers on a twig.
   - (v) Simultaneous maturation of anthers and stigma.
   - (vi) A condition in which the flowers remain closed.
   - (vii) The androecium matures earlier than the gynoecium.
   - (viii) Pollination brought about by wind.
   - (ix) Pollination brought about by insects.
   - (x) Stamens are united to form a single staminal tube.
2. **Define the following terms:**
   - (i) Pollination
   - (ii) Fertilisation
3. **State two advantages and two disadvantages of each:**
   - (i) Self pollination
   - (ii) Cross pollination
4. Given alongside is the longitudinal section of the ovary. Label the parts indicated by guidelines and state the function of the following parts:
   - (i) Integuments
   - (ii) Micropyle
   - (iii) Nucellus



5. **State the fate of each of the following after fertilisation has been affected:**
   - (i) Ovule
   - (ii) Ovary wall
   - (iii) Calyx
   - (iv) Corolla
   - (v) Stigma and Style
   - (vi) Stamens
6. **Give two examples of each:**
   - (i) Insect pollinated flowers
   - (ii) Self pollinated flowers
   - (iii) Wind pollinated flowers
   - (iv) Flowers with bracts
   - (v) Bird pollinated flowers
   - (vi) Flowers with inferior ovary
   - (vii) Water pollinated flowers
   - (viii) Flowers with superior ovary
   - (ix) Unisexual flowers
   - (x) Capitulum inflorescence
7. **State two important characteristics each of the following:**
   - (i) Wind pollinated flowers
   - (ii) Insect pollinated flowers
   - (iii) Water pollinated flowers
   - (iv) Bird pollinated flowers
8. **Briefly explain the following terms:**
   - (i) Double fertilisation
   - (ii) Artificial pollination
9. What is a fruit? State the significance of fruits.
10. What is parthenocarpy? Give two examples of parthenocarpic fruits.

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Artificial Vegetative Propagation

Vegetative propagation is a form of asexual reproduction in plants in which a bud present on any vegetative part of the plant such as root, stem or leaf grows and develops into a new plant. Vegetative propagation may take place by natural or artificial methods.

Artificial Vegetative Propagation

a. **Cutting:** In this method, stems are cut into small pieces and placed in moist soil. Roots arise from the base and develop adventitious buds which grow into shoots.

Examples: Rose, china rose, sugarcane.

b. **Budding and Grafting:** In this type of propagation, a small shoot or bud of a desired variety of flower or fruit is fixed on the stem of another plant.

The receiving plant is called the **host** while the twig that is fixed on it is called the **scion.** According to the type of slit made, grafting can be cleft grafting or whip grafting. Points to be noted while grafting are:

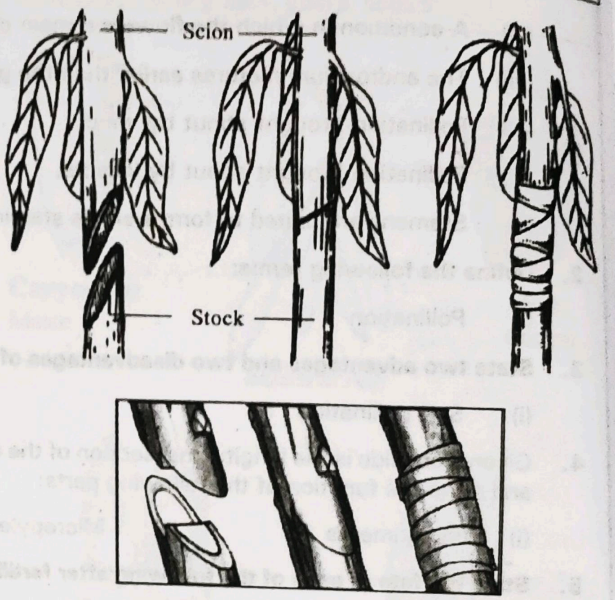
1. The two plants must be related.
2. The cambium layers of the two parts must be in close contact so that growth may continue.
3. The grafted parts must be bound together and the joints coated with **soft wax** to protect against drying up and entry of germs.

In due course of time, the host and scion grow together in union. In case a bud is used as a graft instead of a twig, it is known as **budding.**

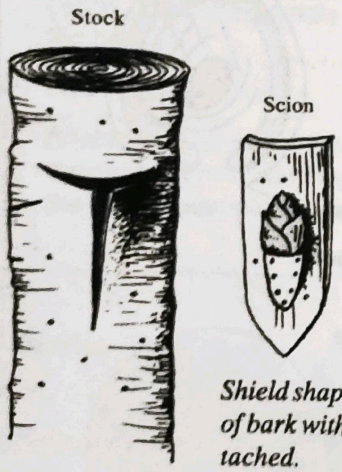
Example: Rose, peach, plum

Methods of Artificial Vegetative Propagation

1. Cutting and grafting
2. Budding grafting and Cleft grafting
3. Layering
4. Tissue Culture



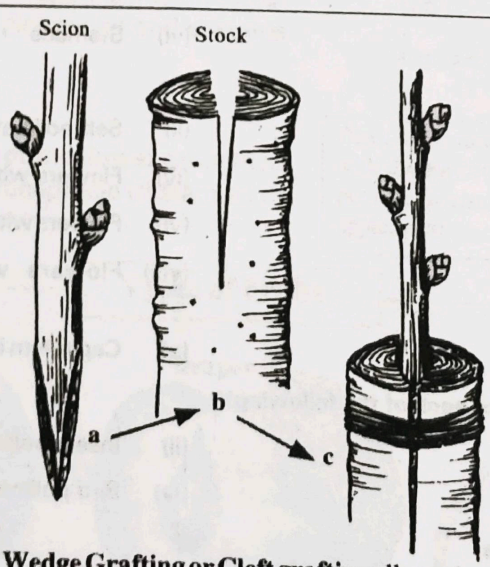
Vegetative propagation by Cutting and Grafting in the Mango plant

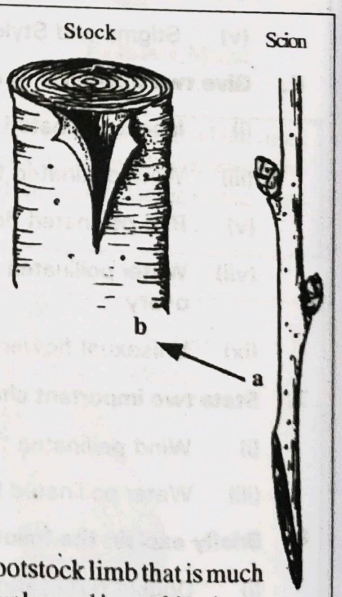


'T' shaped incision in the stock, into which the bud of the scion is inserted.

Shield shaped piece of bark with bud attached.

Bud Grafting





Wedge Grafting or Cleft grafting allows the union of a rootstock limb that is much larger in size than the scion piece. This technique is effectively used in grafting large diameter stock, one and one-half diameter and larger. It is conducted in late winter when both the rootstock and the scion are in a dormant condition and terminated when the sap flow begins.

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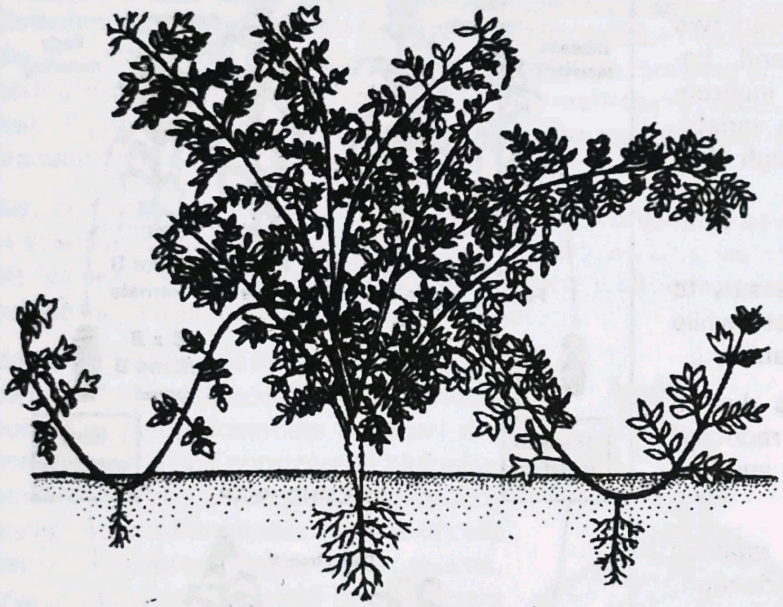
c. **Layering:** In this method, the lower branches of the plant is pinned to the ground and covered with soil some distance from the tip. Roots develop from the covered part of the branch. This portion may be cut off from the parent plant and allowed to grow into a new individual or it can even be replanted elsewhere.

Example: Grape vine



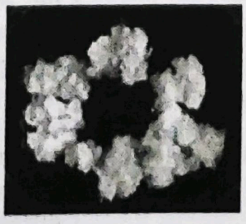
Vegetative propagation by Layering

Tissue Culture or Micropropagation

Plant tissue culture is the technique of **growing plant cells outside an intact plant.** It relies on maintaining plant cells in **aseptic conditions** (sterile) on a **suitable nutrient medium.**

The culture can be sustained as a mass of undifferentiated cells for an extended period of time, or regenerated into whole plants. In plants, this technique is also known as **cloning.**

1. A small piece of tissue is cut from the plant and transferred to a container with nutrient medium under aseptic conditions.
2. The tissue absorbs the nutrients and grows into an unorganised mass of tissue called **callus.**
3. Small quantities of the callus are transferred into another medium which induces differentiation and plantlets are produced.



The new plants retains all the characteristics of the parent plant.

It may be noted that this is a very **tedious and expensive procedure** and hence not as popular as conventional farming methods of sowing and reaping crops.

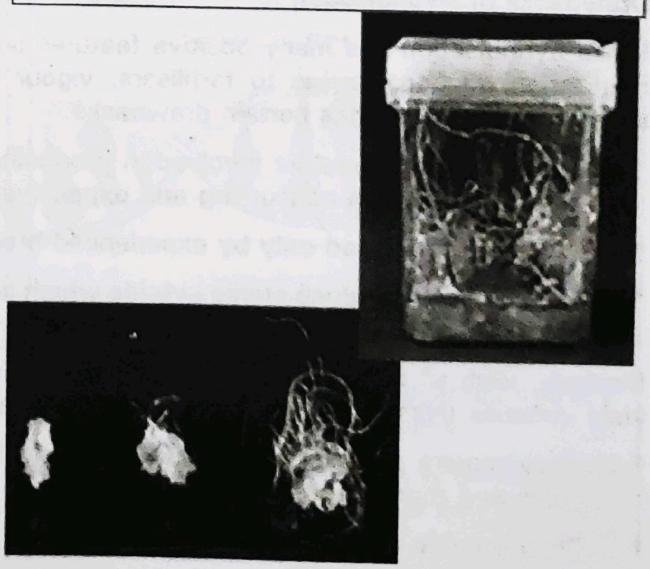
Advantages of Vegetative Propagation

1. It is a surer and quicker method of reproducing a plant, since
   a. The process of pollination and fertilization is eliminated. As such, there is no dependence on pollinating agents.
   b. The new individual continues to receive food from the parent plant for some time and hence can grow even during unfavourable conditions.

   A seed on the other hand, would not germinate into a new plant unless provided with optimum conditions of air, water, temperature and nutrients.
2. The characteristics of the parent plant is preserved and the new individuals develop with identical qualities.
3. Plants that do not produce viable seed (e.g. banana, potato, rose, sugarcane, orange etc. can be propagated by this method.
4. Seedless fruits can be cultivated.

Disadvantages of Vegetative Propagation

1. It never produces new varieties.
2. Vegetative reproduction does not result in widespread distribution but tends to produce dense clumps of daughter plants around the parent. This leads to over crowding and competition for food.



From callus to plantlet

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Hybridisation

Hybridisation is the crossing between genetically dissimilar plants to produce a new kind (hybrid). This method incorporates the good characteristcs of both parents in one variety.

The **crossing** between genetically dissimilar plants to produce a new kind **(hybrid)** is called **hybridisation**. Crossing may be between two different varieties (intervarietal), between two different species of the same genus (interspecific) and between different genera (intergeneric). This method incorporates the good characteristics of both parents in one variety. The two most desirable qualities of food plants are **high yield** and **natural resistance to disease.**

Advantages of Varietal Improvement

(i) **Improved Yield and Quality:** A high yield is necessary to meet the food requirement of populous countries, while good quality of the product increases its marketability.

(ii) **Resistance to biotic and abiotic factors:** Losses due to destruction by pests or environmental factors is reduced. New varieties with better adaptability to different environmental conditions can be developed.

(iii) **Early and uniform maturity:** Early maturing enables multicropping systems, resulting in increased production.

(iv) **Light and heat tolerance :** Most crops are sensitive to light and temperature. Developing varieties that can withstand light and heat will help crossing the cultivation boundaries.

(v) **Favourable agronomic traits:** Desirable features can be bred into the plants. For example, in case of cereals, dwarf crops are favoured because taller plants tend to fall over under the weight of the grains and spoil the crops. For fodder crops, tall, profusely branching plants are preferred.

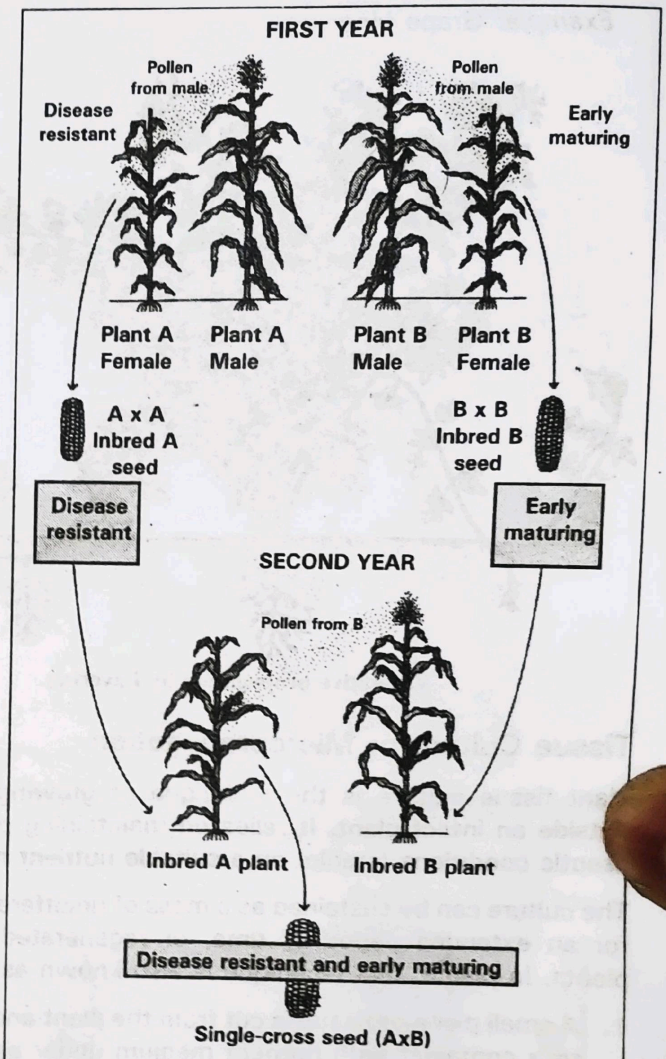
Drawbacks of Hybridisation

While hybridisation has many positive features such as early maturation, responsiveness to fertilisers, vigour etc all in a single variety, it also has certain drawbacks.

- The technical procedure involved in producing hybrids is very tedious, time consuming and expensive.
- It can be performed only by experienced breeders.
- Certain plants produce sterile hybrids which are unable to reproduce.

Similarly, with all the positive features attached to the high-yield varieties (HYV), there are certain disadvantages.

- They require a higher concentration of nutrients, pesticides and more frequent weeding.
- They provide a lesser amount of fodder for the cattle.
- They are highly susceptible to certain specific diseases.



Selected plants are forced to breed with other plants of the same variety. This produces inbred seeds. Two inbred varieties are bred to yield a single-cross seed.

Heterosis or Hybrid Vigour

Hybrid vigour refers to the **increased vigour** displayed by the offspring from a cross between genetically different parents.

Hybrids from crosses between different varieties are often stronger and produce better offsprings than the original varieties. For example, mules, the offspring of mares crossed with donkeys, have greater strength and resistance to disease and a longer lifespan than either parent.

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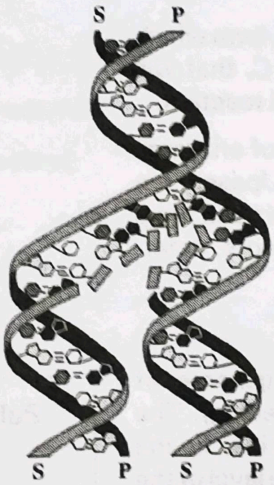
Biotechnology

Any technique that uses living organisms, or parts of organisms, to make or modify products, improve plants or animals, or to develop microorganisms for specific uses is called biotechnology. These include recombinant DNA techniques (genetic engineering) and hybridoma technology (a technique that allows scientists to make specific quantities of antibodies).

Biotechnology is a broad term generally used to describe the use of biology in industrial processes such as agriculture, brewing and baking. Recently, the word has come to refer more to the production of genetically modified organisms or the manufacture of products from genetically modified organisms.

Biotechnology has its roots in the distant past. It originated as a skill used traditionally in the manufacture of beers, wines, cheeses etc, where the techniques of manufacture were well understood but the molecular mechanisms were unknown.

Now, rapid advances in molecular biology, particularly **recombinant DNA (rDNA) technology** is giving scientists a remarkable understanding and control over biological processes. They are now able to directly manipulate the inheritable material of cells between different types of organisms, creating new combination of characters and functions, not previously achievable by traditional breeding methods.



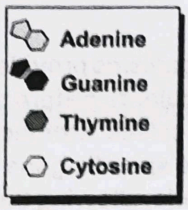
The traditional biotechnology products now include antibiotics, vaccines, monoclonal antibodies and food products.

Role of Biotechnology

In Medicine

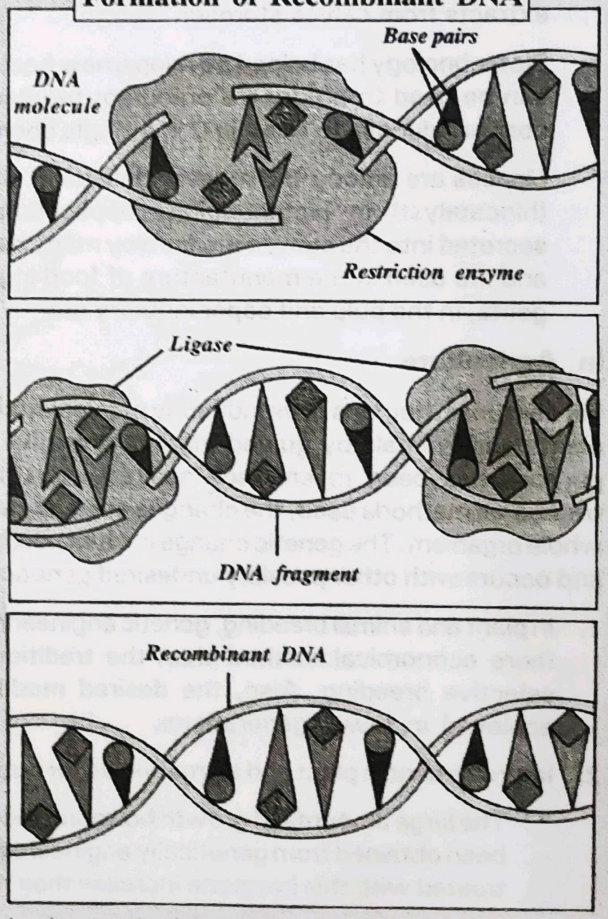
The rDNA technology is seen as a branch of science which will have a profound impact in the following areas of medicine:

1. Diagnosis and cure of hereditary defects and serious diseases. For example,
   - Diabetes is a disease caused by the inability of the cells of the pancreas to produce the hormone insulin. Scientists are able to produce large quantities of insulin in bacterial "factories" by splicing the insulin gene from human cells to plasmids from cells of ***E.coli*** bacteria.
   - Using rDNA techniques, scientists have isolated genes from the cells of unborn babies to determine whether they have inherited defective genes. Doctors may eventually be able to treat babies in the mother's womb itself.
2. Development of new biopharmaceutical drugs and vaccines for human and animal use. Prescription antibiotics like penicillin and tetracycline are now being produced in forms and quantities that allow safe administration to people suffering from bacterial infections.



DNA or deoxyribonucleic acid is a **helically-twisted double chain** polydeoxyribonucleotide macromolecule. Two types of nitrogenous bases occur in DNA, **purines** (A and G) and **pyrimidines** (C and T).

Formation of Recombinant DNA



1. **A gene-sized fragment of DNA is isolated from one organism by means of restriction enzymes. The enzyme separates the molecule lengthwise at a specific sequence of the base pairs.**
2. **After a gene has been isolated, an enzyme called ligase is used to splice (join) the gene to a larger DNA fragment.**
3. **The hybrid molecule formed is called recombinant DNA.**

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In Industry

Industrial application of the results of biological research permits the **production of synthetic hormones or enzymes** by combining genetic material from different species. It helps improve and preserve food products such as cheese, wine, yogurt etc.

* In **cheese production**, biotech is being used extensively to improve protein content and lower fat composition of milk for cheese.

  Enzymes produced by microorganisms provide an alternative to animal rennet (a cheese coagulant). Before biotechnology, rennet came from the lining of calves' stomach. Biotech has enabled researchers to remove specific gene that produces rennet and reproduce it in bacteria, allowing the production of rennet by fermentation. Today, nearly 50% rennet is produced by this method, eliminating much of the need for extracts from calves stomach.

* Biotechnology has helped develop a new bacterial form which can be used to produce a precursor to vitamin C, that will convert glucose to **vitamin C** in a single chemical reaction.

* **Lipases** are among the most widely used class of enzymes (biocatalyst) in biotechnology applications. Lipases are secreted into the culture medium by many bacteria and fungi and are used in the manufacture of food ingredients, detergents, in the pulp and paper industry etc.

In Agriculture

For centuries, humans have indirectly manipulated the genomes of plants and animals by guided mating (selective breeding). The purpose has been to enhance desired characteristics. In the traditional methods used, the changes are made at the level of the whole organism. The genetic change is often poorly characterised, and occurs with other possibly undesired genetic change.

1. In plant and animal breeding, genetic engineering is a faster and more economical method than the traditional methods of selective breeding. Also, the desired modification can be achieved in fewer generations.
2. Improvement in plant and animal yields for nutritional content.
   * The large amounts of growth hormone found in cows have been obtained from genetically engineered bacteria. Cows treated with this hormone increase their milk production.
   * It may be possible alter certain bean plants to produce nutritionally complete protein.
3. Introduction of pest, drought and salinity resistances could allow many crops to be grown in regions previously considered as hostile to plant growth.
4. Genetic engineering also has potential in controlling pollution. Microorganisms may be developed that chemically breakdown garbage into alcohol or natural gas.

Guidelines for Genetic Engineering

In 1976, the National Institutes of Health (NIH) issued safety guidelines to control laboratory procedures for gene-splicing.

These guidelines were gradually relaxed from 1978 to 1982 because such research had proven safer than originally feared.

In 1985, the NIH approved guidelines for treatment in which genes were transplanted to correct hereditary defects.

Public Awareness and Concerns about Genetic Engineering

It is the public attitudes and awareness that will influence the evolution and application of biotechnology in the marketplace. People accept medical applications more readily than they do the manipulation of animal and human genomes. (The totality of DNA present in the cells of a species is its genome). For example, while gamma irradiation of foods was demonstrated to be safe and efficient method to kill pathogenic bacteria, it was not accepted by the lay public after the Chernobyl disaster. This is because most people were not able to differentiate between the process of irradiation and radioactivity. Thus, there are concerns over:

* 'Unknown" health risks.
* Possible effects on environment.
* The "unnaturalness" of transferring genes between unrelated species.

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Exercise 3

1. List the methods of artificial vegetative propagation.
2. State the advantages and disadvantages of artificial vegetative propagation.
3. **Write a short note on:**
   (i) tissue culture
   (ii) layering
4. State the condition that must be satisfied for the successful grafting of two plants.
5. **Name any one plant that is generally propagated by:**
   (i) Bud grafting
   (ii) Cutting
   (iii) Layering
6. Explain how vegetative propagation checks evolution.
7. a. Mention the advantages of tissue culture.
   b. Mention the drawbacks of tissue culture.
8. Define the following terms:
   (i) Biotechnology
   (ii) Hybridisation
9. Put forth the arguments:
   (i) In favour of hybridisation.
   (ii) Against biotechnology.
   (iii) In favour of genetic engineering and against selective breeding.
10. What is meant by hybrid vigour? Explain giving suitable examples.
11. Explain the contribution of biotechnology in the following:
    (i) Cheese production
    (ii) Vitamin C
    (iii) Pollution control
    (iv) Improvement of plant and animal yields for nutritional content
    (v) Pest control

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6
Seed: Types and Germination

Introduction

***A seed** is a mature ovule.*

After fertilisation, a series of changes take place within the ovule. After the fusion of one of the male gametes with the definitive nucleus the latter, now called the endosperm nucleus, begins to grow. It divides and give rise to a large number of small nuclei. Protoplasm collects round of each of the nuclei, and finally cell walls are formed. Thus, a food storage tissue, called **endosperm** or **albumen**, is formed. As it grows it fills up the nucellus.

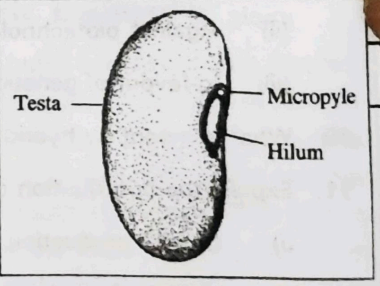
The fertilised egg-cell grows and gives rise to the **embryo.** The embryo is enclosed within a tough protective coat called the **integument** and consists of a plumule, radicle and an embryonic axis, to which one or two cotyledons are attached. A seed may be **endospermic** or **non-endospermic.**

* **Non-endospermic (or exalbuminous) seed:** Seeds without endosperm are known as non-endospermic or exalbuminous seeds. In many seeds no endosperm is seen at maturity although it is always formed at the initial stage of embryo development. This is explained by the fact that the embryo, in the process of development continually draws in the food stored up in the endosperm, and completely exhausts it; so when nothing is left behind the seed becomes **exalbuminous.**

* **Endospermic (or albuminous) seed:** Seeds containing endosperm are known as endospermic seeds.

  In some cases, the endosperm grows very vigorously so that the embryo cannot completely exhaust it; the seed is then said to be **albuminous.** In most cases as the endosperm grows it completely fills up the nucellus space so that no nucellus is found in the seed; but in few cases, as in water lily, ginger family, four o'clock plant and glory of the garden it persists and grows into a nutritive tissue like the endosperm, called the **perisperm.**

Endospermic and non-endospermic seeds exhibit structural differences.

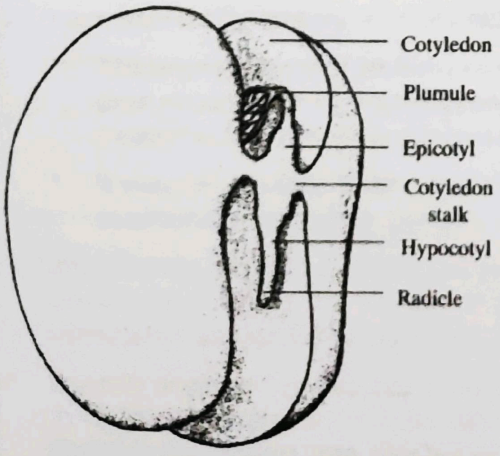


Parts of the Embryonic Axis

Mesocotyl : Portion of the embryonic axis upon which the cotyledons are attached.

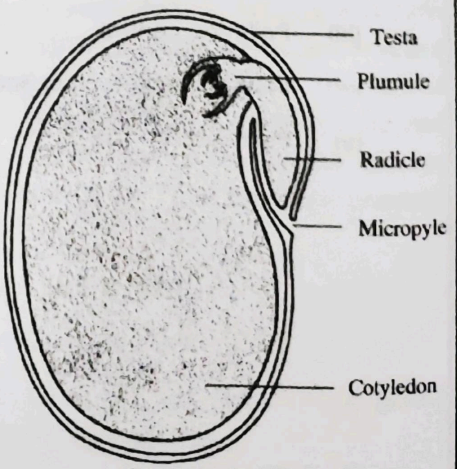
Epicotyl : Portion of the embryonic axis between the mesocotyl and the plumule.

Hypocotyl : Portion of the embryonic axis between the mesocotyl and the radicle.



Embryo plant of a dicotyledon

Ovule	**Seed**
Funicle.....	Stalk
Integuments with hilum, micropyle, raphe and chalaza	Seed coats (testa and tegmen with corresponding parts)
Nucellus.....	Perisperm
Egg-cell.....	Embryo
Definitive nucleus..	Endosperm
Synergids, antipodal cells.....	Disorganised



Section of embryo plant

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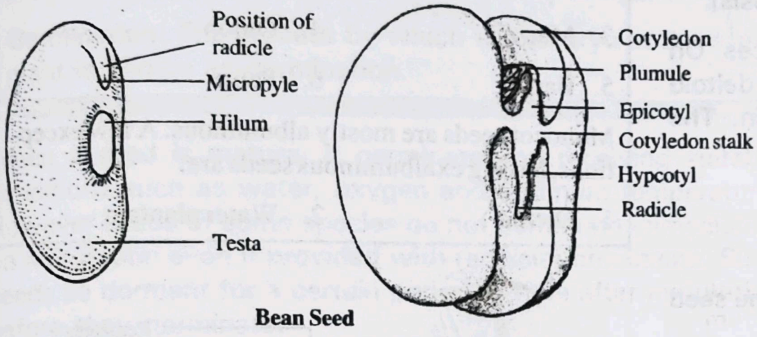
Seed Structure

Parts of Non-endospermic Seed (dicotyledonous)

Example: Bean, Gram, Pea, Mango

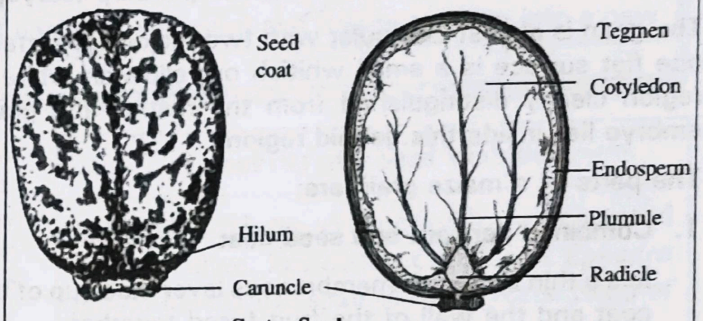


Bean Seed

1. **Seed coat:** It consists of two integuments which may be united or free. They are:
   a. **Testa:** The outer tough protective layer. It protects the seed from fungi, bacteria and insects.
   b. **Tegmen:** Inner thin membrane.
2. **Hilum:** It is a scar left by the stalk and it represents the point of attachment of the ovule to the ovary wall.
3. **Micropyle:** A minute pore or opening above the hilum which allows entry of water into the embryo.
4. **Raphe:** A ridge along the median groove formed by the funicle or stalk. It represents the portion of the stalk which remains fused with the testa.
5. **Embryo:** The embryo consists of the following:
   a. **Cotyledons:** Two fleshy food-laden cotyledons attached to the embryonic axis, providing nourishment to the embryo in the early part of germination.
   b. **Radicle:** The pointed, lower end of the axis is the radicle. It grows and develops into the root system of the plant.
   c. **Plumule:** It is the feathery or leafy end of the axis It grows into the shoot system of the plant.

Parts of Endospermic Seed (dicotyledonous)

Example: Castor, Papaya, Custard apple, *Mirabilis*



Castor Seed

Seed coat: Consists of two coats:

a. **Testa:** Outer hard brittle protective blackish spotted integument.

b. **Tegmen:** Inner thin, membranous whitish integument.

Caruncle: It is a massive outgrowth of the tip of the outer integument formed at the micropyle. It absorbs moisture and helps germination.

Hilum: It remains hidden beneath the caruncle.

Micropyle: It is located between the hilum and the caruncle.

Raphe: Raphe is prominent and forms a low ridge on one side of the caruncle.

Endosperm: Yellowish mass of fleshy storage tissue lying immediately below the tegmen. It is rich in oil.

Embryo: The embryo is thin, flat and lies embedded in the endosperm. It consists of the following:

a. **Cotyledons:** Two large, thin, papery cotyledons with prominently nerved veins attached to the axis.

b. **Radicle:** It is distinct and points outwards.

c. **Plumule:** The epicotyl and plumule remain hidden between the two cotyledons. The plumule bears a number of leaves near its apex.

Bean seed	Castor seed
1. Caruncle absent.	Caruncle present.
2. Endosperm absent.	Thick fleshy endosperm present.
3. Cotyledons fleshy with reserve food.	Cotyledons, thin, papery and veined.
4. Hilum and micropyle are visible.	Hilum and micropyle hidden by the caruncle.

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Parts of Endospermic Seed (monocotyledonous)

Example: Maize

The maize grain is an example of a one seeded fruit in which the seed coat remains fused with the pericarp **(caryopsis).**

The grain is almost triangular with two major flat surfaces. On one flat surface is a small whitish or yellowish white deltoid region clearly distinguished from the rest of the grain. **The embryo lies inside this deltoid region.**

The parts of a maize grain are:

1. **Combined pericarp and seed coat**

   It is a thin brownish membranous layer made up of the seed coat and the wall of the fruit fused together.

2. **Endosperm**

   The grain is obliquely divided into the upper endosperm and the lower embryo by a prominent epithelial layer.

   The larger portion of the endosperm stores **starch.** The outermost layer of the endosperm is rich in **proteins** and is known as the **aleurone layer.**

3. **Embryo**

   The embryo lies obliquely in the lower part of the grain. It consists of the cotyledon, radicle and the plumule.

   a. **Cotyledon:** One shield-shaped papery cotyledon known as the **scutellum.** The surface layer of the scutellum lying in contact with the endosperm is the epithelium. The cells of the epithelium secrete enzymes which digest and absorb food material stored in the endosperm.

   b. **Radicle:** The radicle, covered by a root cap is surrounded by a protective root sheath called the **coleorhiza.**

   c. **Plumule:** The plumule bears a few embryonic leaves and is covered by a conical cap or plumule sheath known as the **coleoptile.**

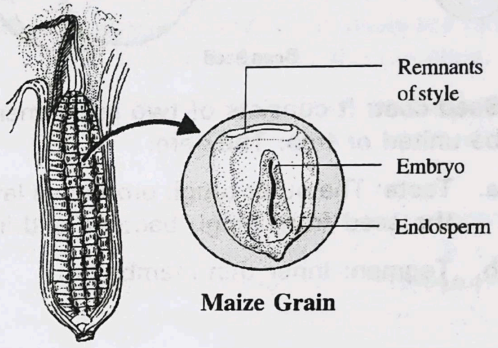
Bean seed	Maize grain
1. Two cotyledons.	One cotyledon.
2. Endosperm absent.	Large prominent endosperm with aleorone layer.
3. Embryo is large.	Embryo is small.
4. Plumule leaves are folded.	Plumule leaves are rolled.
5. Hilum and micropyle are visible.	Hilum and micropyle are not visible.
6. Seed contained separately in the fruit called pod.	Seed coat and fruit wall fused to form a single grain.

Example of Monocotyledonous Albuminous Seeds

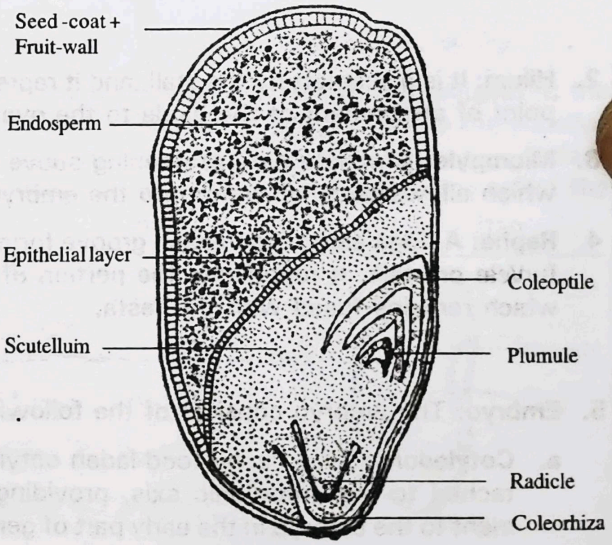
1. Rice
2. Wheat
3. Maize
4. Onion
5. Barley
6. Palms

Monocot seeds are mostly albuminous. A few exceptions, having exalbuminous seeds are:

1. Orchid
2. Water plantain



Maize Grain



Longitudinal Section of the Maize Grain

Reserve Food in Seeds

Seeds often contain large amounts of reserve food. The food may be:

1. **Starch:** *Example* - wheat, maize, rice, barley, oats.
2. **Oils:** *Example* - mustard, castor, sunflower, groundnut.
3. **Proteins and carbohydrates:** Leguminous pulses *(dals)* and pods like peas, beans.

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Seed Germination

Dormancy is defined as the total time period after maturation during which a seed will not germinate even when provided with all the conditions necessary for germination.

Germination: The process by which the embryo in the seed becomes activated and begins to grow into a new plant is known as **germination.**

When a seed is mature, it germinates on receiving suitable conditions such as water, oxygen and optimum temperature. However seeds of some species do not germinate immediately on maturation even if provided with requisite conditions. Such seeds lie dormant for a certain period of time after maturation before they germinate.

Conditions for Germination

A seed which does not undergo dormancy or a seed after its dormancy period is over, will not germinate unless certain conditions are available. These are

A. Presence of Moisture or Water

For vital life processes to occur normally, it is necessary that the protoplasm remain saturated with water:

1. Water is a solvent for most enzymes and salts. In the presence of water, enzymes act upon the food, dissolve and utilise the food stored in the cotyledons or endosperm. Thus, water activates the embryo and is the medium in which chemical reactions leading to germination and growth takes place.
2. Water is absorbed by the seed coat which becomes soft, swells up and bursts open. This facilitates the emergence of the embryo.

Longevity and Seed Viability

Longevity: It is the total period for which a seed can stay alive. For instance, seeds of *Ephedra foliata* have a life span of three years. Seed of *Nelumbo* can live for 70 to 100 years.

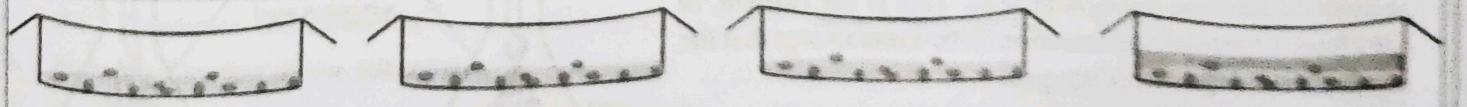
Viability: The presence of life in a seed is viability. If a seed is alive, it is said to be viable. If the seed is dead, it is said to be non-viable.

Conditions Essential for Germination

1. Moisture
2. Optimum temperature
3. Air (or oxygen)

Experimental set-up to demonstrate the significance of Water in Germination

Equal number of seeds from the same source are placed in four separate petri dishes and are exposed to similar conditions of light and temperature for a few days. The dishes are kept covered with lids to prevent evaporation of water.



A: **Soaked seeds placed on moist cotton-wool.**

Seeds germinate properly.

B: **Soaked seeds placed on dry cotton-wool.**

May begin to germinate but shrivels up and dies.

C: **Unsoaked seeds placed on dry cotton-wool.**

No change occurs.

D: **Soaked seeds submerged in water.**

May begin to germinate but eventually rots.

Conclusion: Seeds fail to germinate in the absence of water (C). Adequate water is required for germination to take place (A) and (B). Excess water prevents germination (D). This is due to the fact that once all the dissolved oxygen is utilised by the seed, further germination is arrested since the life-supporting oxygen is now lacking.

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B. A Favourable Temperature

A suitable temperature is necessary for the germination of seed.

* Seeds of tropical plants have an optimum temperature range of 25° to 40°C.
* Seeds of temperate plants have an optimum temperature range of 10° to 20°C.
* Temperatures outside the range of germination cause the seeds to pass into a state of secondary dormancy.

Note: Very low temperatures inhibit the growth of embryo and thus completely prevent germination. High temperatures speed up germination up to a point where either the protoplasm or tissues are destroyed, drying up is too rapid or fungal growth is promoted.

C. Presence of Air (oxygen)

During germination a large amount of energy is required by the activated protoplams to divide and grow.

This energy is provided by the oxidation of the stored food by a process called **respiration.**

Absence of oxygen for a prolonged period results in the death of the germinating seed. That is why seeds planted very deep into the soil, which does not receive a proper supply of oxygen may not germinate.

Effect of Temperature on Germination

Label three petri-dishes A, B and C. Place moist cotton wool along with an equal number of seeds in each dish. Cover the dishes with the lids and place them as instructed for a few days.

A : Leave the dish in a room at ordinary temperature. The seeds germinate.

B : Place the dish in a refrigerator. It is observed that the seeds fail to germinate.

C : Place the dish in an heated oven. It is observed that the seeds fail to germinate.

Conclusion: A certain degree of warmth or optimum temperature is required for germination to occur (A). Extreme temperatures do not favour germination, (B, C).

Controlled Experiments

A controlled experiment is one in which two almost identical experiments are set up.

In one experiment, all the normal conditions are present, while in the other, one or more factors may be eliminated. Any difference in the result can then be attributed to that eliminated factor.

To show that Oxygen is necessary for Germination

The principle of the experiment is to deprive the seeds of oxygen and see how many of them germinate compared with others having normal supply of oxygen.

* **Set up 'A':** A piece of wet cotton wool is rolled on some cress seeds which will stick to it. The cotton wool is suspended from a tread inside a tightly corked **flask A**. The flask contains **alkaline pyrogallic acid** which absorbs oxygen.
* **Set-up 'B':** A similar flask is set up which contains water instead of alkaline pyrogallic acid. This is the **control**, in which the experimental situation is the same except that the seeds are not deprived of oxygen.

Both flasks are placed in the same conditions of light and temperature.

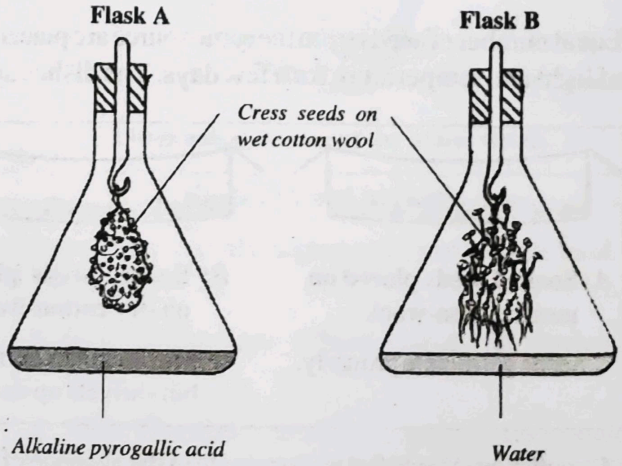
Observation: **Set-up 'A':** Seeds germinate

Set-up 'B': Seeds do not germinate

Conclusion: Oxygen is necessary for germination. The seeds in 'B' receive all the normal conditions for germination while in 'A' oxygen has been eliminated. Hence, no germination occurs in 'A'.

Note: Pyrogallic acid itself does not absorb oxygen. Hence, it is mixed with an equal quantity of potassium hydroxide and made alkaline. This alkaline pyrogallic acid can absorb oxygen.

Being highly caustic, care must be taken that it does not fall on the seeds and damage them.



Experiment to show that Oxygen is Necessary for Germination

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The Three Bean Experiment

Aim: To show that air, water and optimum temperature are necessary for germination.

Apparatus: A beaker partly filled with water, a wooden plate, three bean seeds, pins.

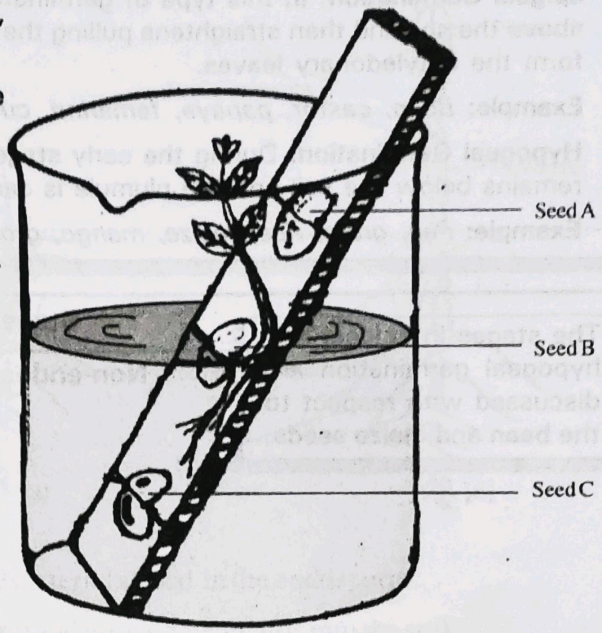
Procedure: The three bean seeds are fixed to the wooden plate as described.

Seed A: Positioned on the plate above the water level, exposed to air only.

Seed B: Partly submerged in water, and partly exposed to air.

Seed C: Completely submerged in the water.

The beaker is then kept in a warm place for a few days.



Observations

Seed A: Does not germinate.

Seed B: Germinates properly.

Seed C: Begins to germinate, but germination is arrested.

Conclusion: The experiment shows that air and water are necessary for germination though the effect of temperature is only indirectly proved.

Seed A receives oxygen but no water.

Seed C receives water but barely enough oxygen (dissolved in the water). Hence it may begin to germinate but soon stops.

Seed B receives both, oxygen and water, hence germinates properly.

Since the entire apparatus is kept at an optimum temperature, the significance of temperature may also be inferred.

A **seedling** is a stage in the growth of a plant before it has become wholly independent of the food stored in it.

Exercise 1

1. **Define:**
   (i) Seed (ii) Seedling
2. **Differentiate between:**
   (i) Albuminous seed and exalbuminous seed. (ii) Epicotyl and hypocotyl.
   (iii) Coleorhiza and coleoptile. (iv) Radicle and plumule
3. **State the function of the following:**
   (i) Testa (ii) Micropyle (iii) Cotyledons in pea
   (iv) Aleurone layer in maize (v) Epithelium in maize (vi) Caruncle in castor seed
4. A seed is provided with all the conditions necessary for germination. Yet it fails to germinate. Can you conclude that the seed is dead? Explain.
5. Briefly explain the factors that are necessary for germination.
6. **Give two examples each of:**
   (i) Monocotyledonous albuminous seeds.
   (ii) Monocotyledonous ex-albuminous seeds.
   (iii) Dicotyledonous albuminous seeds.

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Types of Germination

Two main types of germination are recognised as Epigeal Germination and Hypogeal Germination

1. **Epigeal Germination:** In this type of germination the hypocotyl elongates rapidly, arches upwards, comes above the soil and then straightens pulling the cotyledons above the soil. The cotyledons become green and form the cotyledonary leaves.

   Example: *Bean, castor, papaya, tamarind, cucumber, cotton*

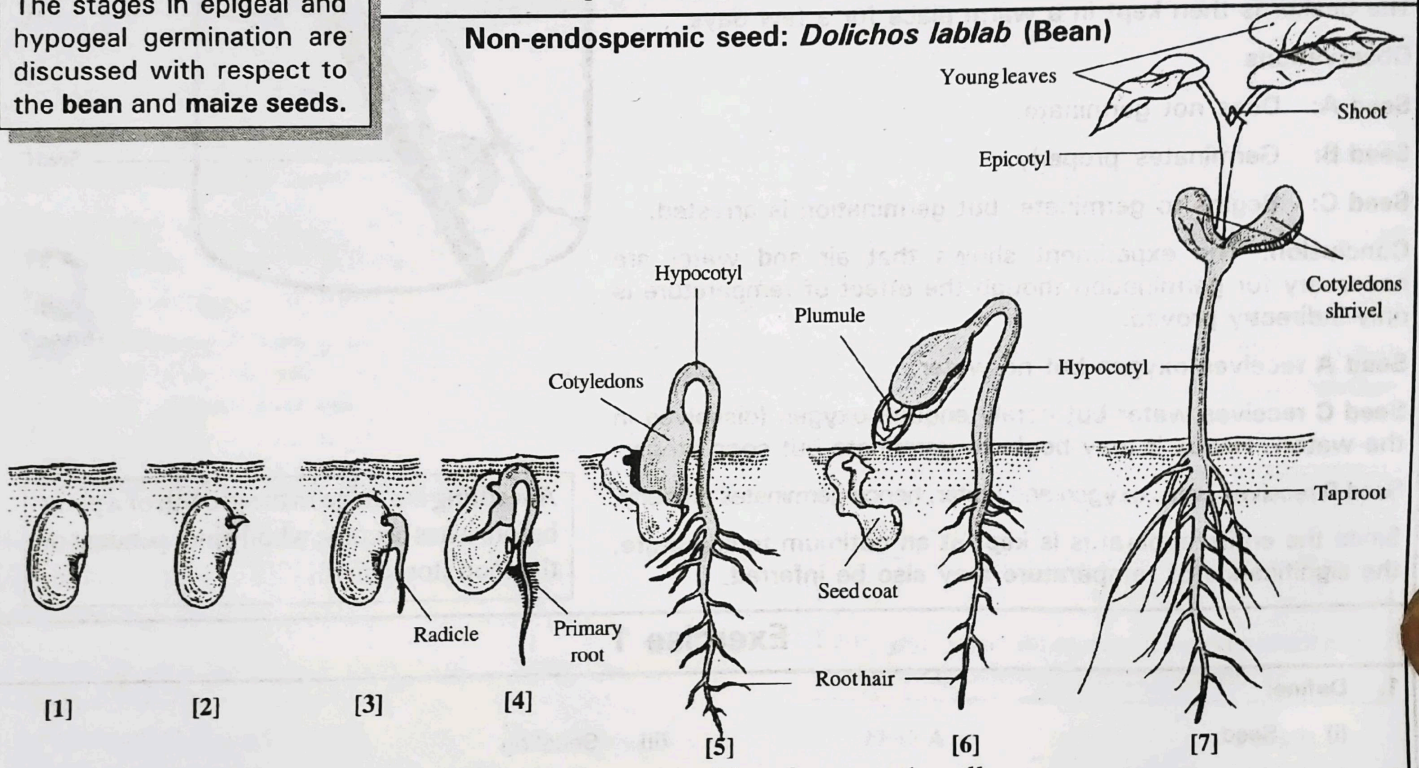
2. **Hypogeal Germination:** During the early stages of the germination, the epicotyl elongates. The cotyledon remains below the soil and the plumule is carried at the tip of the elongated epicotyl.

   Example: *Pea, gram, rice, maize, mango, groundnut*

The stages in epigeal and hypogeal germination are discussed with respect to the **bean** and **maize seeds.**

Stages in Epigeal Germination

Non-endospermic seed: *Dolichos lablab* (Bean)



1. Under favourable conditions the seed imbibes large quantities of water and swells up.
2. The seed coat ruptures at the radicular end.
3. The radicle pierces out of the seed coat, bends downwards and grows into the soil.
4. The radicle forms the primary root. Lateral roots begin to emerge. Root hairs appear in the region where elongation has ceased. Water and salts absorbed by the root hairs are passed onto the seedling. Meanwhile the hypocotyl elongates and arches upwards above the soil. The two cotyledons are within the ruptured seed coat.
5. The hypocotyl straightens, pulling the cotyledons into the air. The ruptured seed coats may remain below the soil or are shed above the soil.
6. The hypocotyl becomes completely erect. The two cotyledons diverge to form the flat, green cotyledonary leaves. The epicotyl elongates, bearing at its tip the plumule.
7. Young leaves unfold at the tip of the epicotyl. The cotyledons shrivel up and are shed. The primary root gives branches and persists all through the life of the plant (tap root). The young leaves now prepare food for the plant.

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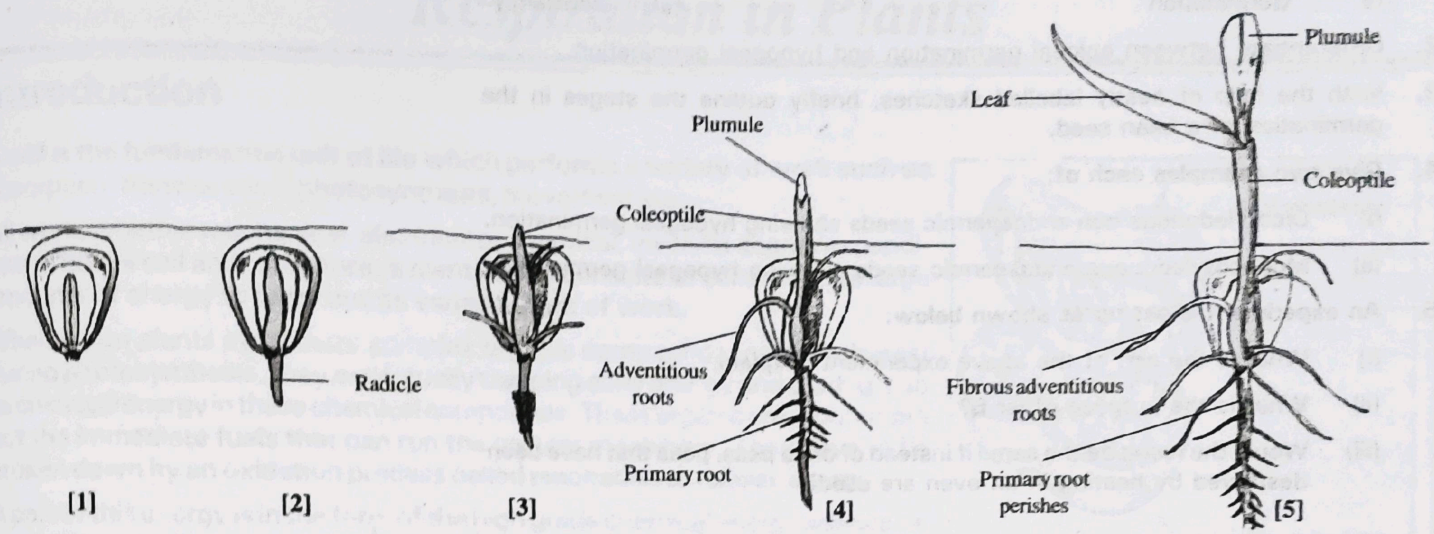
Stages in Hypogeal Germination

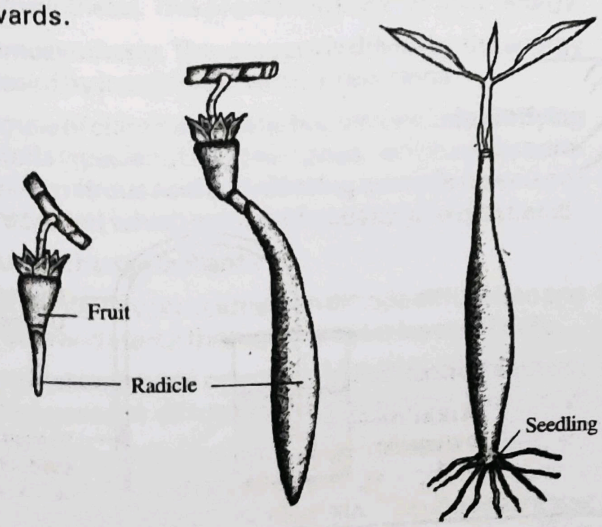
Monocotyledonous Endospermic seed: *Zee mays* (Maize)



1. The seed absorbs water and swells. The cotyledons absorb food material stored in the endosperm.
2. The radicle pierces through the protective root sheath (coleorhiza) and grows downwards into the soil.
3. The coleoptile elongates and pierces out of the grain opposite in direction to the coleorhiza. The radicle develops into the primary root with root hairs.
4. A cluster of fibrous roots arise around the base of the primary root. These develop from the base of the stem. The first leaf of the plumule pierces out of the coleoptile which now forms a tube-like collar around its base.
5. More leaves appear in succession. Primary root perishes giving rise to a fibrous root system.

Viviparous Germination

It is a special type of germination in mangroves where the seeds do not show dormancy and begin to germinate while the fruit is still attached to the tree. After germination, the young seedling drops into the saline water with the radicle end downwards.



Epigeal	Hypogeal
1. Hypocotyl elongates.	Epicotyl elongates.
2. Cotyledons come above the soil.	Cotyledons remain below the soil.

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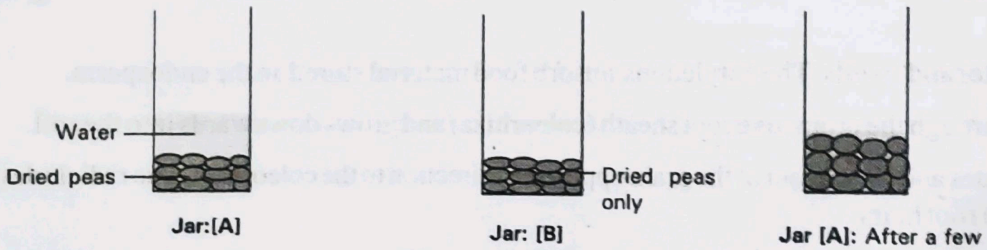
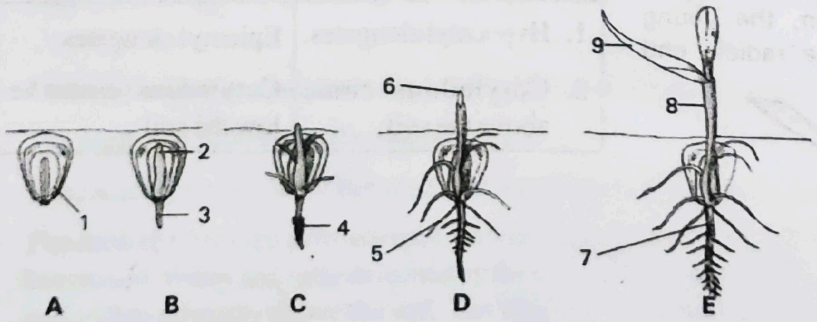
Exercise 2

1. **Define:**
   (i) Germination (ii) Dormancy
2. Differentiate between epigeal germination and hypogeal germination.
3. With the help of neatly labelled sketches, briefly outline the stages in the germination of a bean seed.
4. **Give two examples each of:**
   (i) Dicotyledonous non-endospermic seeds showing hypogeal germination.
   (ii) Monocotyledonous endospermic seeds showing hypogeal germination.
5. **An experiment is set up as shown below:**
   (i) What is the aim of the above experiment? Explain..
   (ii) What is the purpose of jar B?
   (iii) Would the result be the same if instead of dried peas, peas that have been destroyed by heating in an oven are used?

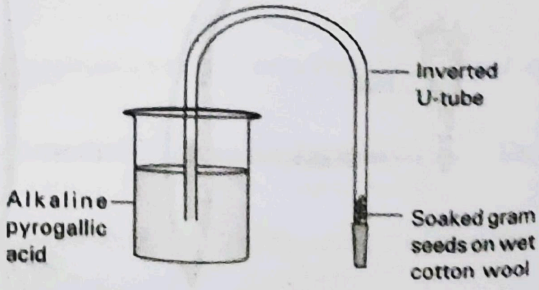


Jar:[A] Jar: [B] Jar [A]: After a few days

6. What is meant by 'viviparous' germination?
7. **Shown below are the stages of a certain type of germination.**
   (i) Is the structure A a seed or a fruit? Give reason.
   (ii) Label the parts 1 to 9.
   (iii) State the function of 2, 7, 9.
   (iv) What kind of germination is shown?



8. The experiment is designed to prove a condition necessary for germination.
   (i) State the condition.
   (ii) Why has the level of alkaline pyrogallic acid risen in the limb of the U-tube?
   (iii) Suggest a suitable control for the experiment.



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7
Respiration in Plants

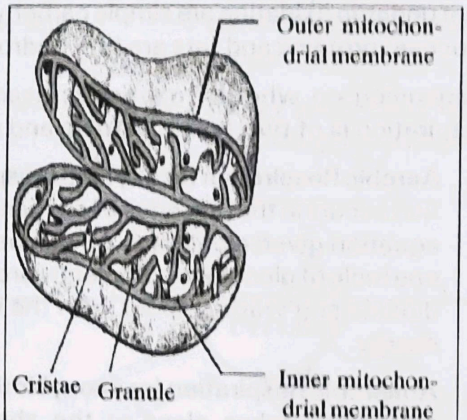
Introduction

A cell is the fundamental unit of life which performs a variety of work such as absorption, translocation, photosynthesis, movement etc.

All work, whether mechanical, electrical or chemical, involves energy expenditure. Thus, a cell and, therefore, a plant which consists of cells requires large amounts of energy to carry out its varied nature of work.

When green plants synthesize complex organic compounds (carbohydrates) during **photosynthesis,** they are actually trapping solar energy and storing it up as chemical energy in these chemical compounds. These organic compounds are not the immediate fuels that can run the cellular machinery. They have to be broken down by an oxidation process called **respiration** to release energy.

A part of this energy is in the form of the high grade chemical energy **adenosine triphosphate** (ATP). The energy required to carry out any kind of work is provided by ATP. When the energy released in the form of ATP is used up, it is converted to **adenosine diphosphate** (ADP) by the addition of a phosphate group. When more energy is available by further breakdown of glucose, ADP is converted to ATP.



The mitochondria in the cell is the seat of respiration

Depending on whether oxygen is used in the process or not, respiration is of two types — **aerobic** and **anaerobic**. Aerobic respiration proceeds in the presence oxygen, while anaerobic respiration proceeds in the absence of oxygen.

The process of respiration takes place in two steps called **glycolysis** and **Krebs cycle.**

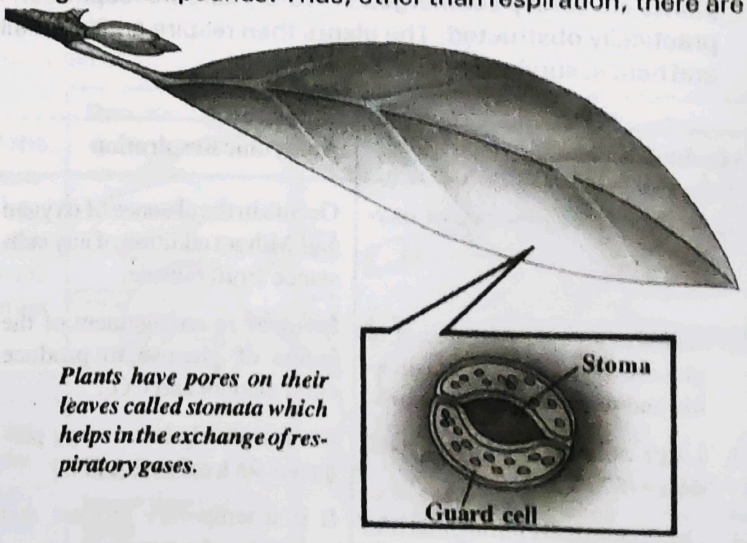
1. **Glycolysis:** An **anaerobic** process which takes place in the cytoplasm with the help of several enzymes. During this process, glucose is converted to **pyruvic acid.**
2. **Krebs Cycle:** This is **aerobic** in character and takes place inside the **mitochondria** with the help of enzymes. During this process, pyruvic acid is converted into carbon dioxide and water vapour.

Certain aerobic bacteria are able to oxidise inorganic compounds with the release of energy. These chemical reactions are exothermic, i.e., they proceed with the liberation of heat. The energy released from these reactions is utilised by the bacteria for the synthesis of carbohydrates and other organic compounds. Thus, other than respiration, there are other processes in plants that release energy.

a. **Photosynthesis:** This process is driven by solar energy.

b. **Chemosynthesis:** This process is driven by the energy released by inorganic chemical reactions.

   Example of chemosynthetic bacteria include **nitrifying bacteria** (species of *Nitrosomonas)* which oxidise ammonia to nitrous acid and **nitrating bacteria** (species of *Nitrobacter*) which oxidise nitrous acid to nitric acid.



Plants have pores on their leaves called stomata which helps in the exchange of respiratory gases.

Gaseous Exchange in Plants

In higher plants, oxygen and carbon dioxide diffuse into and out of roots and stems through the **outer layers of cells.**

* Woody stems have openings called **lenticels** which allows gases to diffuse in and out of the plant body.
* The majority of the gas exchange in plants, however, takes place through small openings in the leaves and herbaceous stems called **stomata.** The loose arrangement of the spongy mesophyll tissues in the leaves gives rise to air spaces inside the leaf which facilitates the efficient exchange of gases.

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Respiration

Respiration is a catabolic process by which an organism assimilates oxygen, oxidises organic substances and releases carbon dioxide, water vapour and energy.

Respiration is a process of oxidation or breaking down of organic compounds, particularly simple carbohydrates like glucose, in the living cells, with the release of energy. The reserve food material that undergo oxidation are simple carbohydrates. In the absence of glucose, proteins and fats are first hydrolysed and then oxidised.

Depending on whether oxygen is used in the process or not, respiration is of two types: **aerobic** and **anaerobic**.

a. **Aerobic Respiration (or oxybiotic respiration):** Aerobic respiration occurs in the presence of oxygen and is represented by the equation given alongside. As can be seen from the reaction, one mole of glucose is completely broken down to yield carbon dioxide and water vapour with the liberation of 674 k cal of energy.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + 674\,\text{k cal} + \text{heat energy (or 38 ATP)}$$

b. **Anaerobic Respiration (or anoxybiotic respiration):** Anaerobic respiration takes place in the absence of oxygen and is represented by the equation alongside. From the equation it is clear that there is no addition of any substance from outside. It only involves a rearrangement of the atoms of glucose to form two molecules each of ethyl alcohol and carbon dioxide with the release of 28 k cals of energy.

Therefore, the process is called **intra-molecular respiration.**

$$C_6H_{12}O_6 \xrightarrow{\text{in plants}} 2C_2H_5OH\ (\text{ethyl alcohol}) + 2CO_2 + 28\,\text{k cal} + \text{heat (or 2 ATP)}$$

$$C_6H_{12}O_6 \xrightarrow{\text{in animals}} 2CH_3CHOHCOOH\ (\text{lactic acid}) + 2ATP + \text{heat}$$

It is a normal process in certain microscopic bacteria and fungi. Fruits and seeds also may sometimes respire anaerobically. In most other plants, it is a temporary process and the ability possessed by plants to respire anaerobically is of tremendous survival value.

Under adverse conditions, such as flooding, when terrestrial plants are totally submerged in water, aerobic respiration is practically obstructed. The plants then respire anaerobically and hence, survive.

Aerobic Respiration	Anaerobic Respiration
1. Occurs in the presence of oxygen.	Occurs in the absence of oxygen and without addition of any substance from outside.
2. Involves complete oxidation of glucose to produce carbon dioxide and water vapour.	Involves re-arrangement of the atoms of glucose to produce ethyl alcohol and CO_2.
3. Large amounts of energy produced (674 k cal).	Comparatively less energy produced, 28 k cal or 2 ATP.
4. Occurs normally throughout life.	It is a temporary process that occurs for short periods.

Fermentation

Under anaerobic conditions certain microorganisms like **yeast convert sugar into alcohol and/or into simpler organic substance with the production of carbon dioxide and water vapour.** This process which is similar to anaerobic respiration can be shown by the following equation.

$$C_6H_{12}O_6 \xrightarrow{Zymase} 2C_2H_5OH + 2CO_2 + 28\,\text{k cal}$$

Fermentation is of great commercial importance and is used in the manufacture of alcohol, acetic acid, lactic acid, curing of tobacco and a variety of other commercial products.

Fermentation differs from anaerobic respiration in the following ways:

1. Fermentation occurs in substrates outside the cell.
2. It occurs by the enzymatic action of certain bacteria and fungi (yeast) on the substrate which is in a liquid medium.

A substrate is a substance on which an organism acts and usually derives its nourishment from.

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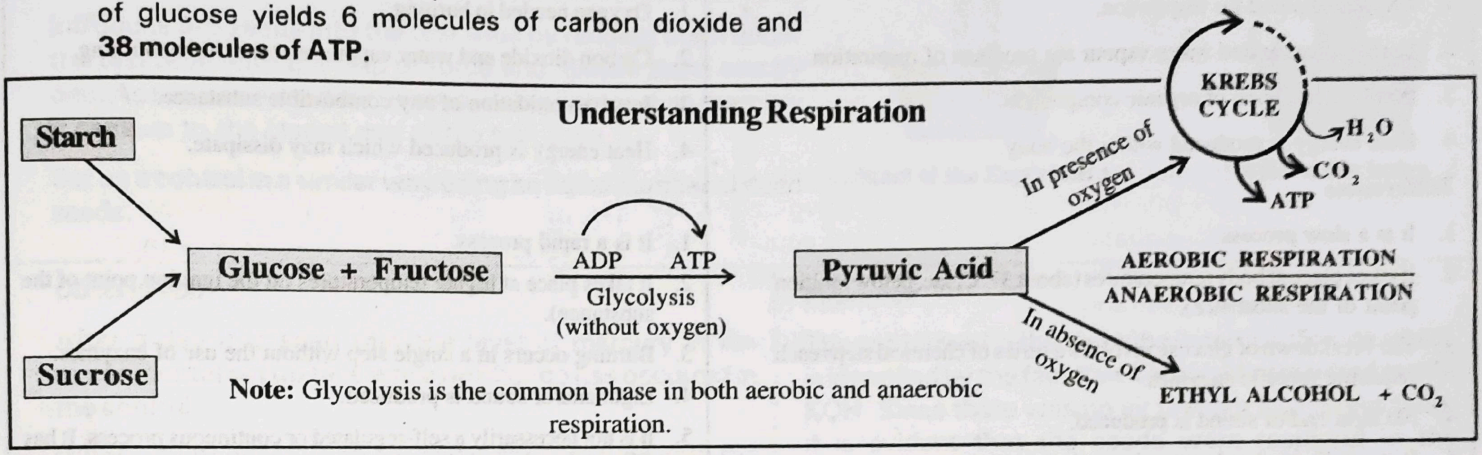
Energy Production in Respiration

The process of cellular respiration takes place in two steps called **glycolysis** and **Krebs cycle.**

1. **Glycolysis:** It is an **anaerobic** process which takes place in the **cytoplasm** with the help of several enzymes. In this phase ATP is converted to ADP. This initiates the process of respiration leading to the formation of phosphoglyceric acid (PGA) and finally pyruvic acid. Thus, during this process, **glucose** is converted to **pyruvic acid** through a chain of intermediate reactions.
2. **Krebs Cycle:** This is **aerobic** in character and takes place inside the **mitochondria** with the help of enzymes. During this process pyruvic acid is converted into **carbon dioxide** and **water vapour.** The complete oxidation of one molecule of glucose yields 6 molecules of carbon dioxide and **38 molecules of ATP.**

Glycolysis	Krebs Cycle
1. Anaerobic process.	Aerobic process.
2. Occurs in the cytoplasm of the cell.	Occurs in the mitochondria of the cell.
3. Converts glucose into pyruvic acid.	Converts pyruvic acid into carbon dioxide and water vapour.
4. Much less energy is produced due to incomplete oxidation.	Energy produced is high due to complete oxidation.

Understanding Respiration



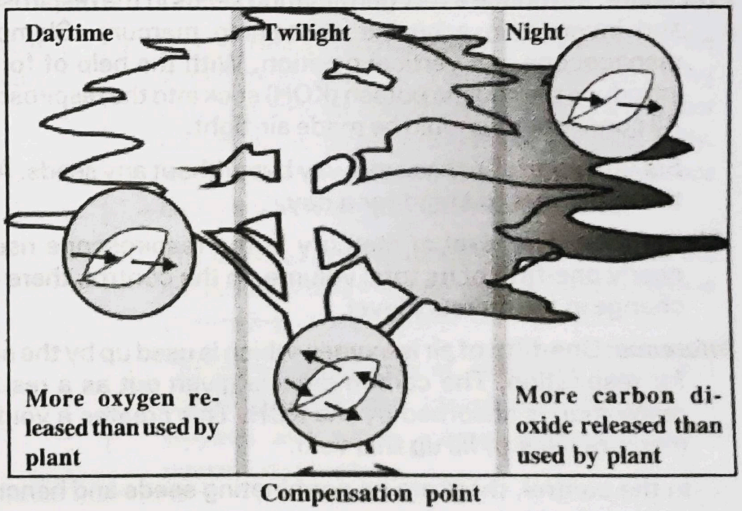
Note: Glycolysis is the common phase in both aerobic and anaerobic respiration.

Respiration and Photosynthesis

Respiration and photosynthesis are two major contrasting metabolic processes involving gaseous exchanges within the plant.

* Respiration is a **catabolic process** utilising carbohydrates as the raw material to produce carbon dioxide and water, photosynthesis is an **anabolic process** using carbon dioxide and water to produce carbohydrates. As a result of respiration, the **plant loses weight** while photosynthesis results in the **gain of dry weight.**
* Respiration can **occur in all living cells** at all times of the day and night. Photosynthesis is restricted to **chlorophyllous cells** and occurs in the **presence of light,** i.e., during the day only. Thus, during some parts of the day respiration exceeds photosynthesis, at some times photosynthesis exceeds respiration and at some times both are equal.

Note: Oxygen produced in photosynthesis is used in respiration this is known as **photorespiration.**



Compensation Point: The low light intensity at which the rate of photosynthesis equals that of respiration is known as compensation point. At this point, the gas evolved in one process is the amount just sufficient for the other, i.e., respiration and photosynthesis balance each other and apparently there is no gaseous exchange.

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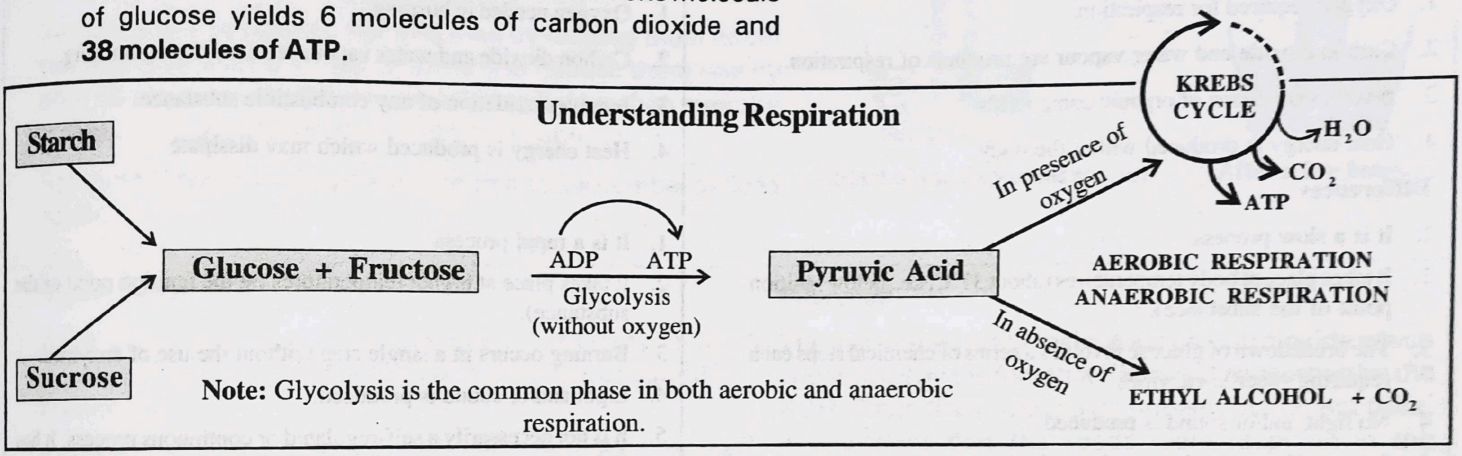

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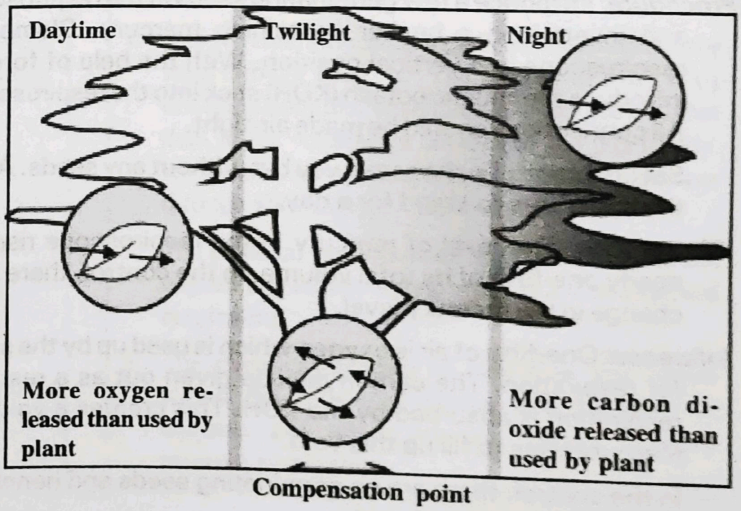

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Respiration and Burning

It is seen that during respiration, **carbon dioxide, water and heat energy are formed.**

When coal is burnt at high temperatures, it also forms **carbon dioxide, water and releases energy.**

Although the two processes, i.e., respiration and burning are fundamentally of oxidation, they differ in several aspects.

A comparative study of the two processes is given below:

Respiration	Burning
Similarities	
1. Oxygen required for respiration.	1. Oxygen needed in burning.
2. Carbon dioxide and water vapour are products of respiration.	2. Carbon dioxide and water vapour released during burning.
3. Involves oxidation of organic compounds.	3. Involves oxidation of any combustible substance.
4. Heat energy is produced within the body.	4. Heat energy is produced which may dissipate.
Differences	
1. It is a slow process.	1. It is a rapid process.
2. It takes place at body temperatures (about 37°C, i.e., below ignition point of the substance).	2. It takes place at higher temperatures (at the ignition point of the substance).
3. The breakdown of glucose involves a series of chemical steps each requiring specific enzymes.	3. Burning occurs in a single step without the use of enzymes.
4. No light and/or sound is produced.	4. Light and/or sound is produced.
5. It is a self-regulated, natural, continuous process.	5. It is not necessarily a self-regulated or continuous process. It has to be initiated.

Experiments on Respiration

Experiment 1

Aim: To demonstrate aerobic respiration.

Apparatus: A respiroscope (flask with bent stem) beaker, stand with a clamp, mercury, caustic potash stick, germinating seeds, forceps.

Procedure: Introduce a few germinating seeds in the respiroscope and invert it in a beaker containing mercury. Clamp the respiroscope in a vertical position. With the help of forceps introduce the caustic potash (KOH) stick into the respiroscope. All connections should be made air-tight.

Set up a control in the same way but without any seeds. Allow the apparatus to stand for a day.

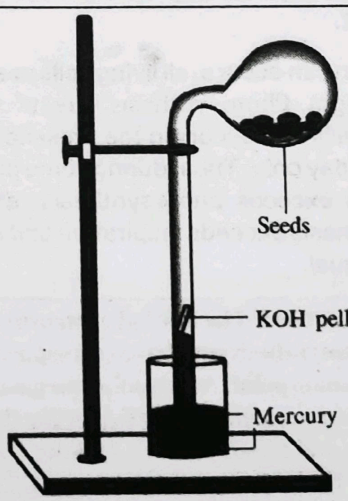
Observation: The level of mercury in the respiroscope rises to nearly one-fifth of its total volume. In the control, there is no change in the mercury level.

Inference: One-fifth of air is oxygen which is used up by the seeds for respiration. The carbon dioxide given out as a result of respiration is absorbed by the KOH. This creates a void and mercury rises to fill up this void.

In the control, there are no germinating seeds and hence, no carbon dioxide is produced.

Respiroscope: *An apparatus used to demonstrate the process of respiration.*

Respirometer: *An apparatus used for measuring the rate of respiration.*



Experiment to demonstrate Aerobic Respiration

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Experiment 2

Aim: To demonstrate anaerobic respiration in germinating seeds.

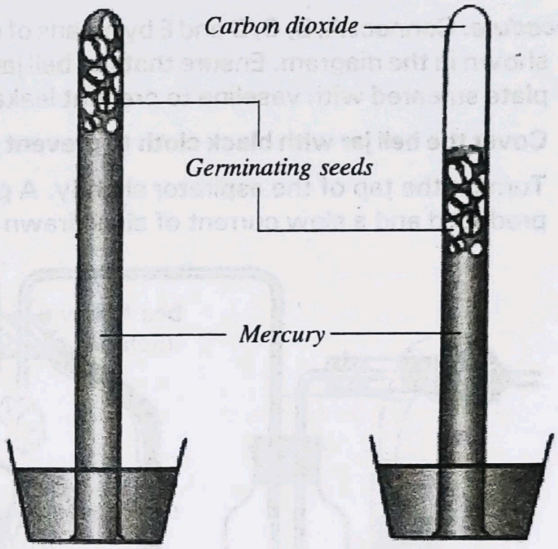
Apparatus: A test-tube, mercury, beaker, germinating seeds, forceps, dead seeds.

Procedure: Completely fill the test tube with mercury. Close the open end of the test tube with the thumb and invert it in a beaker containing mercury. Remove the thumb only after the mouth of the test tube is below the surface of mercury to ensure that no air enters the test tube. Clamp the test tube in a vertical position to the stand.

Remove the testa of a few germinating seeds that have been soaked in distilled water overnight. **The seed coat is removed to ensure that no air (O_2) is enclosed within it.** Using soaked seeds keeps the seeds moist during the experiment.

Introduce 5-6 seeds into the test tube by holding them under the test tube with the help of force and release them one by one. As soon as a seed is released, being lighter than mercury it rises up to the closed end of the test tube.

Set up a control in a similar way using an equal number of dead seeds.



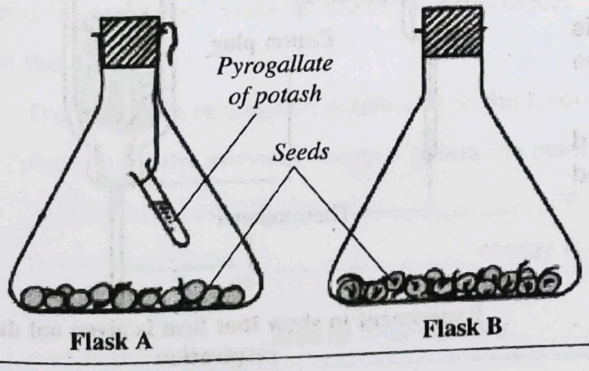
Start of the Experiment **After a few hours**

Observation	***Inference***
After a day it is seen that the level of mercury in the experimental set up falls while no change has occurred in the control. When a KOH pellet is introduced in the test tube with the help of a forcep, it floats on mercury and the mercury rises and fills up the test tube.	The gas formed in the test tube is carbon dioxide which is identified by the fact that it is quickly absorbed by the KOH. Since there was no air present in the test tube, it is evident that the seeds were respiring in the absence of oxygen and giving out carbon dioxide.

To show that Oxygen is essential for Respiration

Soaked seeds are placed in two flasks, A and B. In flask A, a small tube is introduced which contains freshly prepared pyrogallate of potash [made by dissolving pyrogallic crystals in excess caustic potash (KOH)]. This absorbs all the oxygen in the flask.

It is observed that the seeds in flask A fail to germinate , while the seeds in flask B germinate. This shows that oxygen is necessary for providing the energy for growth.



Points to Note

1. Oxygen enters a leaf through the stomata and into the stem through lenticels. The process of entry is by diffusion since the concentration of oxygen is higher than in the respiratory cavities of the plant body. Roots also have aerating pores on their surface through which oxygen enters by diffusion.
2. The **physical process of diffusion**, which does not require any energy or enzymes, is called **external respiration**.
3. The **chemical process of oxidation** that occurs within the cells and tissues with the help of enzymes and which releases energy, is called **internal respiration.**

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Experiment 3

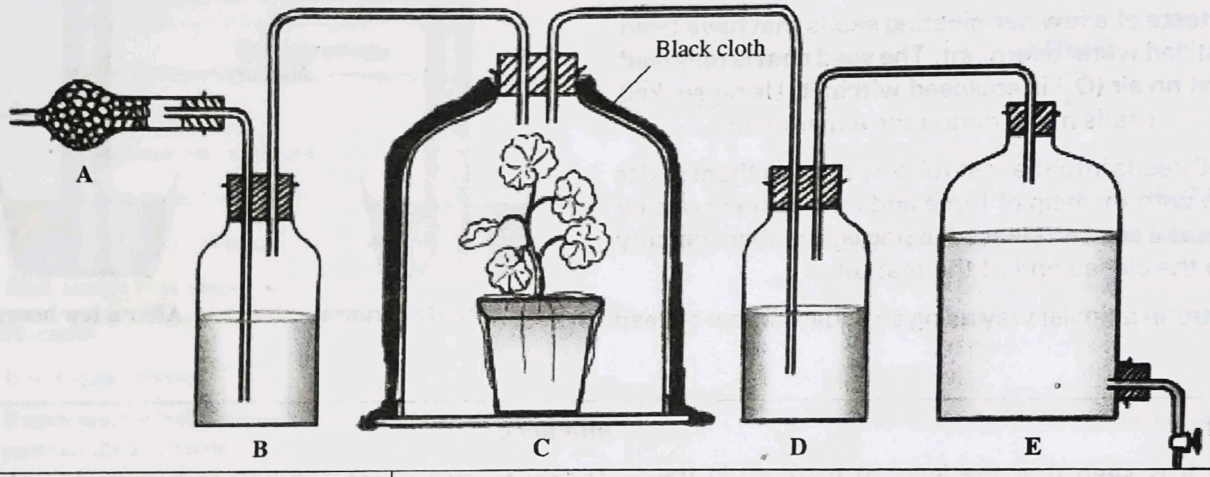
Aim: To prove that carbon dioxide is released in respiration of green plants.

Procedure: Connect A, B, C, D and E by means of delivery tubes as shown in the diagram. Ensure that the bell jar stands on a flat plate smeared with vaseline to prevent leakage of air.

Cover the bell jar with black cloth to prevent photosynthesis.

Turn on the tap of the aspirator slightly. A partial vacuum is produced and a slow current of air is drawn from A to E.

A: A tube containing soda lime.
B: A bottle containing clear lime water.
C: A bell jar enclosing a potted plant.
D: A bottle containing clear lime water.
E: Aspirator containing water.



Observation	*Inference*
1. Lime water in B remains clear.	Air passing through B is free of CO_2 since the CO_2 of the air has already been absorbed by the soda lime in A. Hence, lime water in B does not turn milky.
2. Lime water in D turns milky.	Lime water in D turns milky indicating that the CO_2 must have been released by the plant in C

Experiment 4

Aim: To show that heat is generated during respiration.

Apparatus: Two thermos flasks, two thermometers, germinating seeds, cotton.

Procedure

Flask A: Fill with germinating seeds which have been surface sterilised with 0.1% aqueous solution of mercuric chloride ($HgCl_2$). This is done to kill any bacteria whose respiration may interfere with the experiment.

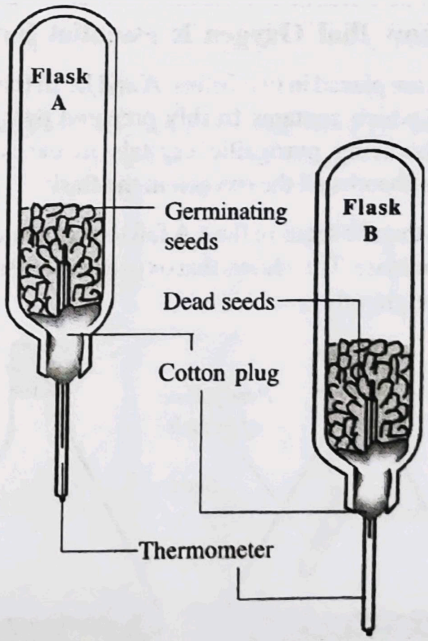
Insert a thermometer into the flask such that its bulb is completely covered with the seeds and pack the mouth of the flask with cotton.

Flask B: Fill with equal quantity of seeds that have been killed by boiling and surface sterilised. A thermometer is introduced in it and the mouth is packed with cotton.

Flask A: A rapid rise in temperature is observed.

Flask B: No change in temperature is observed.

Inference: Respiring seeds evolve heat.



Experiment to show that heat is given out during respiration

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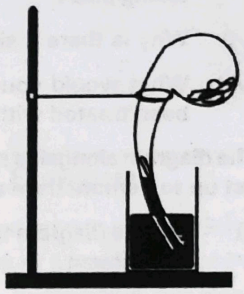
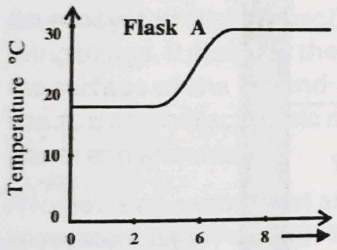
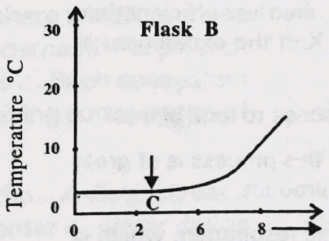
Exercise

1. Define respiration.
2. **Differentiate between:**
   (i) Respiration and Breathing
   (ii) Aerobic respiration and Anaerobic respiration
   (iii) Glycolysis and Krebs Cycle
   (iv) Respiration and Burning
   (v) Respiration and Photosynthesis
3. Germinating seeds are placed in the bulb of a respiroscope. The stem is inverted and introduced in a beaker of mercury. A stick of caustic potash is also introduced in the stem. After a few hours the mercury was seen to have risen in the stem.



   (i) State the aim of the experiment.
   (ii) Why did the mercury rise in the stem?
   (iii) At the end of the experiment, what volume of the retort would you expect to be occupied by mercury?
   (iv) What difference might you expect to note if the stick of KOH was omitted from the apparatus? Explain your answer.
4. **The following graphs show the results of an experiment conducted with seeds taken in two separate flasks.**





Flask A : Soaked gram seeds wrapped in moist cotton wool and placed in vacuum flask A.

Flask B : Gram seeds placed in water bath at 80°C for 15 minutes, cooled to room temperature, wrapped in moist cotton wool and then placed in flask B.

Both flasks are fitted with thermometers in cotton wool plugs.

   (i) Account for the differences between the two graphs.
   (ii) What does point C on the graph of flask B represent?
5. What is fermentation? State its economic importance.
6. **Fill in the blanks:**
   (i) The energy in respiration is released in the form of _____.
   (ii) Apart from the stomata, oxygen enters the plant through _____.
   (iii) Respiration occurs in the _____ of cells.
   (iv) During respiration _____ energy is converted to _____ energy.
   (v) _____ respires anaerobically.

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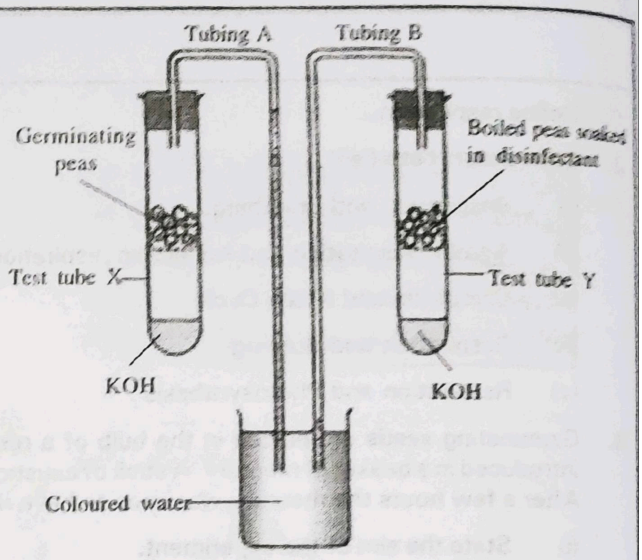
7. **The following diagram refers to an apparatus which is used to demonstrate a physiological process.**



(i) What is the purpose of keeping potassium hydroxide solution in test tubes X and Y?

(ii) What is the purpose of keeping boiled peas soaked in a disinfectant in test tube Y?

(iii) Why has the coloured water risen in tubing A?

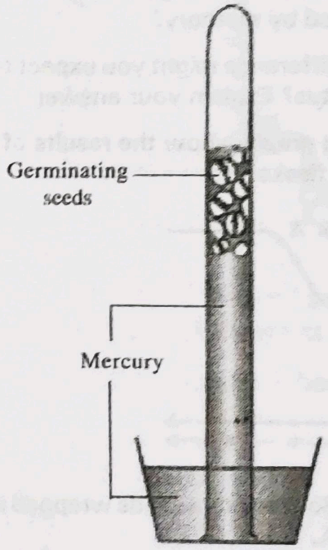
(iv) Name the biological process which causes the water to rise in the tube.

(v) Name the products formed in X as a result of the process taking place.

(vi) Why is there a slight rise of water in tubing B?

(vii) What would you observe if the boiled peas in Y had not been treated with the disinfectant?

8. **The diagram alongside shows the result of an experiment that was set up to demonstrate anaerobic respiration.**



(i) Draw a diagram to show the arrangement at the start of the experiment.

(ii) Name the gas that has accumulated in the space above the seeds.

(iii) What would happen if the gas is allowed to accumulate?

(iv) Why is this type of respiration considered less efficient than the type taking place in test tube X in the experiment in question 1?

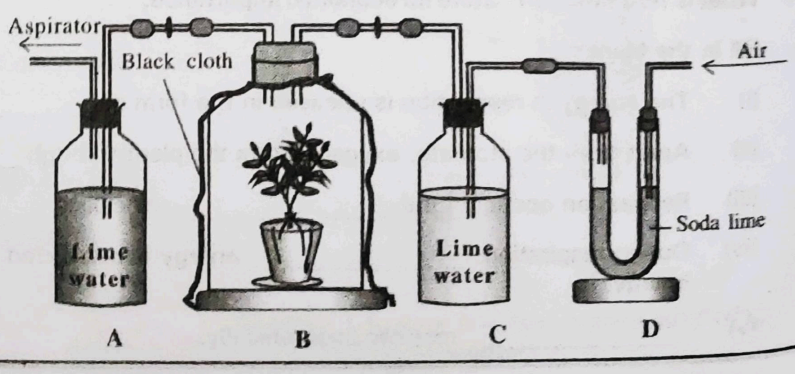
(v) What is the significance of this process to land plants?

(vi) One of the products formed during this process is of great commercial importance. Name the product.

(vii) Name a process, similar to anaerobic respiration, which is used extensively in industry to manufacture the substance named in (vi).

(viii) In what way does the process named in (v) differ from anaerobic respiration.

9. **The apparatus shown alongside is used to demonstrate an experiment related to respiration.**



(i) What is the aim of the experiment?

(ii) State your observations with respect to Flask A and Flask C.

(iii) State the function of soda lime in D.

(iv) Why is B covered with a black cloth?

(v) What would you observe if the potted plant in B were to be replaced by:

a. moist seeds?

b. a small animal like a mouse?

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8
Understanding the Ecosystem

Introduction

Every living organism on earth is a member of a dynamic community known as an **ecosystem.**

An ecosystem is a complex that consists not only of **living creatures** (biotic components) but also of **non-living matter** (abiotic components) and of **radiant solar energy.**

The Earth is the only planet known to have life.

* The living part of the planet is called the **biosphere.** The **biosphere** extends a little way above and below the surface of the planet. The biosphere is also called the **'global ecosystem'.**

  [The term ecosystem was coined by Sir Arthur Tansley in 1935].

* A **biome** is the largest recognisable terrestrial unit (or ecosystem) of the biosphere. Rainforests and deserts are examples of biomes.

* An **ecosystem** is a distinct area in the biosphere which contains living things. It includes the rocks and soil underneath the ground, the surface of the ground and the air above it. Each ecosystem has its own characteristic climate, soil, and living communities of plants and animals.

  A forest is an example of an ecosystem. Although distinct, each ecosystem is not closed. **Sunlight** and **air** enter it, **water** drains from it, **nutrients** enter and leave through the **soil**, and **plant, seeds and animals** come and go.

* Within an ecosystem there are several **habitats.** A habitat is the natural home of a group of plant and animals. This group of living things is called a **community.**

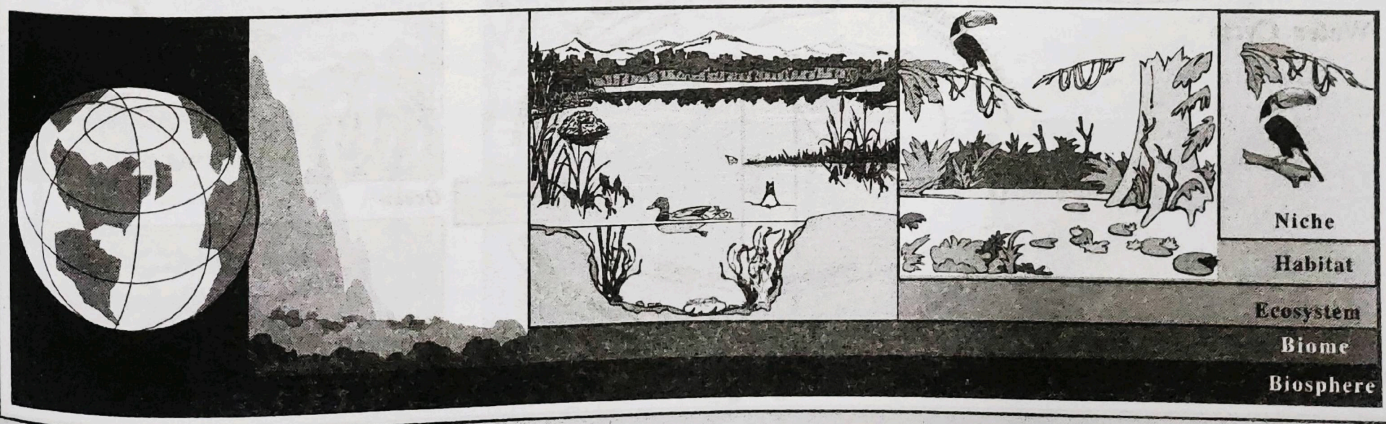
The study of living things in their natural surroundings is called **ecology,** and their natural surroundings is called their **environment.**

Size of Ecosystem

The size of an ecosystem can vary widely. It may be a whole forest or a small pond or even a drop of water. The human skin can also be studied as an ecosystem as colonies of bacteria and mites live here.

Different ecosystems are often separated by geographical barriers like mountains, oceans, and deserts. But these borders are never rigid.

Ecosystems tend to mix or blend with one another. Thus, the whole Earth can be looked upon as one single ecosystem, or a lake or pond can be divided into several ecosystems.



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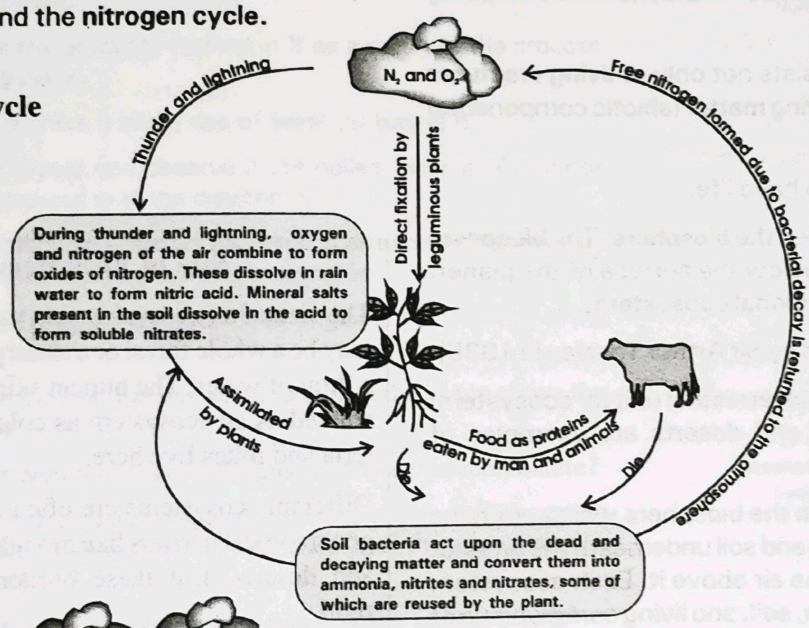
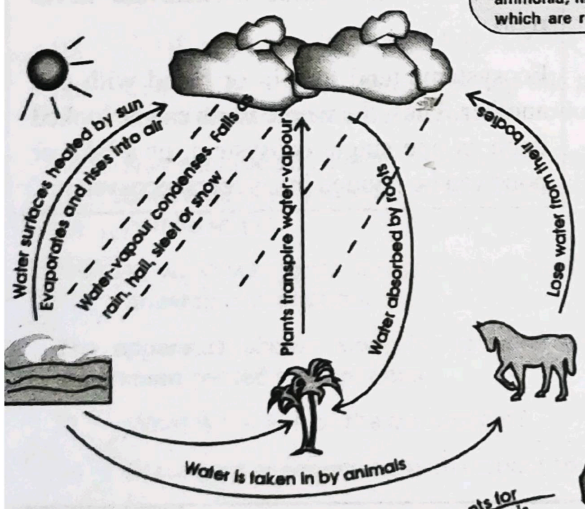
All living organisms depend upon their environment for their proper growth and existence. It is the environment, whether air, water or soil, that provides the organism with water, food and the life supporting element, oxygen. For an environment to be functional in serving its inhabitants, all its various components must be maintained in definite amount and proportion to each other. **Disturbance to any component of the environment is harmful.**

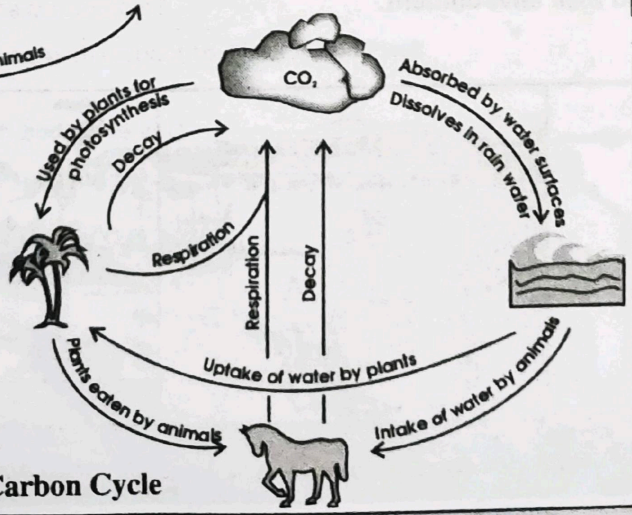
Nature plays an important role in maintaining the vital balance among the components of the environment. This can be seen from the **carbon cycle, water cycle** and the **nitrogen cycle.**

Nitrogen Cycle



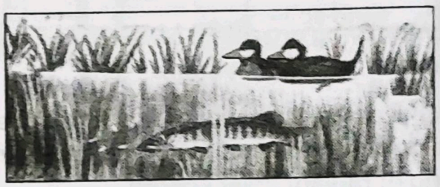


Water Cycle



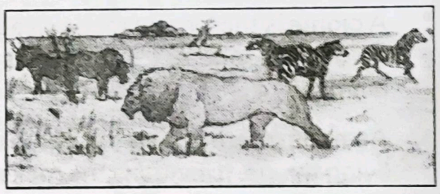
Carbon Cycle

Ecosystems are distributed over the Earth mainly according to climate. The climatic zones range from cold and dry at the Poles to hot and wet at the Equator. Plants and animals are adapted to the conditions and have particular roles within each ecosystem, competing for the resources to survive.



Freshwater lake

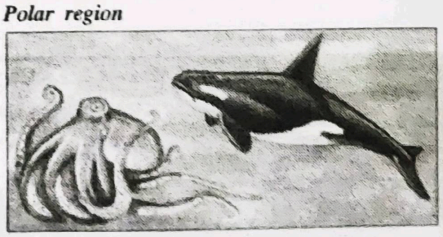
Forest



Grassland

Desert

Polar region



Ocean

Wetland

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Non-living Components of the Biosphere

The Earth is the only planet of the solar system that supports life. Life is possible because of its unique lithosphere, hydrosphere and atmosphere.

1. Lithosphere (source of soil and minerals)

It is the solid outer layer of the Earth which includes the crust and solid part of the mantle down to 75 km. The uppermost layer of the Earth's crust is capable of supporting life and is called **soil.** The soil provides the **nutrients** for all land organisms, directly or indirectly.

2. Hydrosphere (source of water)

Water, which is freely available in the gaseous, liquid and solid state, is necessary for carrying out chemical reactions within the bodies of living organisms. Water also dissolves and transports nutrients from the soil to the plants. It is used by plants for making food.

3. Atmosphere (source of air, wind)

It maintains an **even temperature** on the Earth. It **protects** organisms from the harmful ultra-violet radiations of the Sun.

The gases in the atmosphere support life. **Oxygen** helps in respiration, **carbon dioxide** helps in food manufacture by green plants, and **nitrogen** helps in growth.

Biosphere (source of flora and fauna)

Life is possible only where the lithosphere, hydrosphere and the atmosphere come in contact. Together they provide conditions necessary for life.

The part of the Earth where life exists is called the **biosphere.**

Exchange of matter takes place in the lithosphere, hydrosphere and atmosphere.

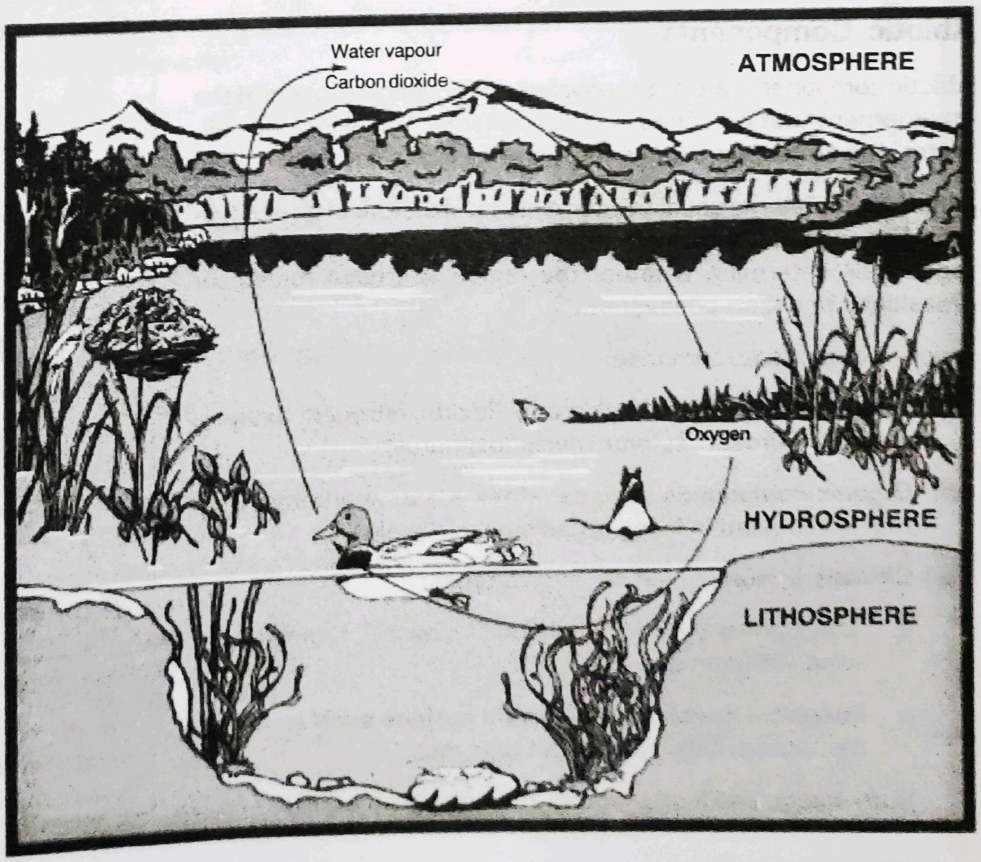
The three spheres of the Earth-the atmosphere, the lithosphere and the hydrosphere together make possible the fourth sphere, the biosphere.

Points to Note

1. **Non-living** substances like air, soil and water constitute the **abiotic** part of the environment.
   - * **Air** includes gases like oxygen, nitrogen, carbon dioxide and water vapour.
   - * **Soil** includes microorganisms, minerals and nutrients.
2. **Living** organisms constitute the **biotic part** of the environment.
3. **Physical factors** like temperature, pressure, rainfall, humidity, etc. (i.e., **climate**) is vital to the natural environment.

   The type of organisms and where they are found depends on it. **Plants and animals adapt themselves to the changing environment.**

   Organisms that are able to adapt to the changing environment survive and those unable to adapt become extinct. In some cases, new species come into existence.



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Structural and Functional Aspects of an Ecosystem

The two most important aspects of an ecosystem are its **architecture** and **working process**.

* Architecture of an ecosystem refers to the structural component of the ecosystem, i.e., the living (biotic) and non-living (abiotic) factors.
* Working process of an ecosystem refers to the functional component i.e., the rate of energy flow and the rate of material or nutrient cycles.

Components of Ecosystem

Structural		Functional	
Abiotic	**Biotic**	**Energy Flow**	**Biogeochemical Cycles**
* *Energy*	*Producers*	*Food chains*	*The Water Cycle*
* *Water*	*Consumers*	*Food web*	*The Carbon Cycle*
* *Air*	*Decomposers*		*The Nitrogen Cycle*
* *Soil*			*The Phosphorus Cycle*
* *Gravity*			

Structural Aspects of Ecosystem

Abiotic Components

Abiotic components are all the physical and chemical aspects of the environment that influence living organisms. These include soil, water, the atmosphere and energy from various sources.

Abiotic components usually determine the structure of an ecosystem. For example, the amount of water or rainfall of a particular region will determine whether the region will have forests or grasslands or desert ecosystem.

Abiotic components comprise:

(i) **Inorganic substances** like carbon dioxide, nitrogen, oxygen, carbon, hydrogen, sulphur, and phosphorus.

(ii) **Organic compounds** such as proteins, fats, carbohydrates that are present in living organisms.

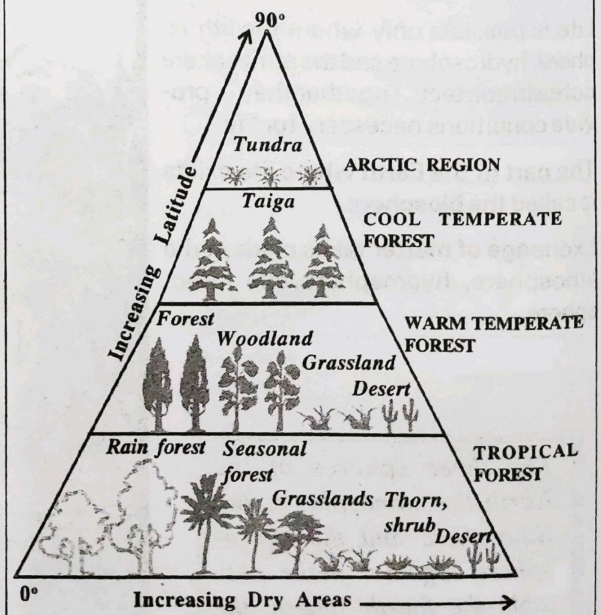
(iii) **Climatic factors** which are of two types:

a. **Atmosphere** such as light, humidity, rainfall, temperature, wind, altitude, etc.

b. **Edaphic** – pertaining to earth's surface such as rivers, mountains, hills, valleys and soil types.

Both abiotic and biotic factors influence each other.

Abiotic and Biotic factors influence each other



The amount of moisture and temperature in an area control the distribution of plants in an area as shown in the diagram above.

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Abiotic Factors

Inorganic Substances

The various metabolic processes taking place in the bodies of living organisms require at least forty different kinds of elements like calcium, phosphorus, nitrogen, etc. in varying quantities.

Elements such as carbon, hydrogen, oxygen, nitrogen and potassium which are required in large amounts are called **macronutrients** whereas the elements like copper, manganese, boron, silicon, molybdenum, etc. which are required in small amounts are called **micronutrients.**

Some of these micronutrients can act as a **limiting factor** and affect the growth and survival of the organisms.

Inorganic elements and their importance for the survival and growth of living organisms is summarised in the table below:

Limiting Factors

If an environmental factor necessary for the survival of living organisms is absent or too low, the factor then becomes a limiting factor for the survival of species.

Example: If the oxygen content in water becomes low, even if food is in abundance then oxygen becomes a limiting factor for survival of fishes.

Limiting factors can be both biotic and abiotic.

Example: The abiotic factors like light, water, soil, temperature, and atmospheric gases – can all become limiting factors.

Element	Utility and Function
1. Carbon, Hydrogen, Oxygen	Basic component of protoplasm – in Carbohydrates, Fats, Proteins
2. Nitrogen	Component of protein necessary for growth
3. Phosphorus	Component of nucleic aids and bone
4. Sulphur	Many proteins contain sulphur
5. Magnesium	One of the components of chlorophyll
6. Iron	Main component of haemoglobin of Red Blood Cells on mammals
7. Sodium	Major component of fluids in animals – important for transmission of nerve impulses
8. Potassium	Important for transmission of impulses
9. Calcium	Helps in formation of bones and teeth in animals

Organic substances are composed of carbohydrates, proteins, fats and their derivatives. These are formed in the soil when dead bodies of plants and animals are decomposed by micro-organisms. In their simple forms, proteins, sugars, etc. are absorbed by plants and when plants are eaten by animals these substances enter the animals body.

Decomposition of organic substances releases nutrients in the soil.

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Impact of Physical Factors on the Ecosystem

Soil, air, water and **light** are necessary for the survival of plants and animals. Loss of any of these factors affect the survival of organisms of a particular region.

Ecological Relations of Soil

a. **Soil Climate:** The amount of air, humidity and temperature of a soil determines the type of living organisms in it. If the temperature increases or if air is depleted, the flora and fauna of the soil is greatly affected.

b. **Soil Temperature:** The absorption of heat by the soil depends on the exposure of the soil to the Sun. Lighter soils absorb less heat than dark soils. Variation in temperature can influence the organisms in the soil.

c. **Soil Water:** Water in the soil is necessary for the survival of plants. The pores in the soil determine the water holding capacity of the soil. Sandy soils have very little water holding capacity. Thus, plant life in deserts is very less.

d. **Soil Chemistry:** Minerals like aluminium, silicon, calcium, magnesium, sodium, potassium, iron and trace elements like cadmium, chromium, lithium, rubidium, vanadium are present in soils.

   * Trace elements decrease plant growth.
   * Calcium-rich soils have low acidity. Snails, earthworms, etc. are more is such soils.
   * If the soil becomes too saline then plants and animals cannot survive in such soils.

e. **Soil pH:** pH refers to the hydrogen ion concentration of a solution.

   Majority of the plants can grow well in slightly acidic soils but if the acidity increases i.e., if the pH is less than 4.5 then it is unfit for the survival of plants and animals.

f. **Soil Enzymes:** Chemical substances produced by roots of plants, microorganisms and having a catalytic effect in specific biological reactions are called soil enzymes.

   Many bacteria produce extracellular enzymes. These help in breaking down organic substances and release minerals in the soil. If the microorganisms are destroyed, the mineral content of the soil gets depleted, thereby affecting plant and animal life.

g. **Biota of the soil:** This is the complex flora and fauna of the soil. The number of organisms in the soil depends on the nature of the soil, the amount of nutrients in the soil and the pH of the soil.

   Particular microorganisms, mainly bacteria, that live in the soil determine the mineral content in the soil. These are the decomposers in the soil.

Physically Dry Soil

Soil, which cannot hold much, water and allows water to percolate to the deeper layers,for example, **sandy soil.**

Plants cannot absorb this water.

Physiologically Dry Soil

Soil, which holds a large amount of water but the water, contains a large amount of dissolved salt, i.e., **saline.**

Plants do not absorb this type of water.

Soil is the most efficient recycling system on Earth. It teams with tiny creatures that mix and process the soil, and keep it healthy.

Some soils are very fertile, others are not, but they support all other life on Earth-from the Amazon rainforest to the Arctic tundra.

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Ecological Relation of Water

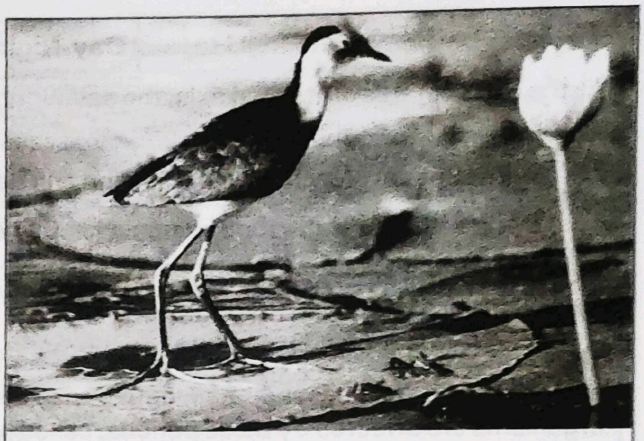
Water plays a very important role in the growth of plants and animals. It is necessary for carrying out all the vital functions in the body such as respiration, circulation, excretion, etc.

a. Salinity of water

This is the amount of dissolved salts in the water. This acts as an important factor to determine the number of species of plants and animals distributed in the various regions of the Earth.

b. Water and Habitat

Both aquatic and terrestrial habitats are affected by the scarcity or abundance of water. Too much or too little water can have adverse effects on the survival of organisms in the habitat. It is essential that a proper water balance be maintained between the internal environment (inside the body) and external environment (in the surroundings) of an organism.



Wetland plants and animals are adapted to survive in their habitat. For example, this jacana, with its amazingly long toes uses water-lily leaves as floating platforms. The water-lily manages to remain afloat because of its buoyant stem and leaves.

Impact of Water on different Habitats

Marine fish live in highly saline surroundings. They concentrate salts in their bodies and thus are able to survive in the seas. On the other hand river and fresh water fish are able to get rid of the excess water that may enter their bodies due to osmosis. These fishes can either survive in seawater or fresh water.

Amphibians can live on land and water. Frogs and salamanders keep entering the water to keep their skin moist. Thus, if the pond or lake dries up these animals are severely affected.

Thus, the distribution of organisms is greatly controlled by availability of water.

Ecological Relation of Light

Sunlight provides the energy for all life on Earth.

The intensity, duration and quality of light have a great impact on the survival of plants and animals. The amount of light reaching the land and water bodies varies.

Causes of Variations in Light Intensity

On land, the variations in light intensity are caused by:

* The **latitude,** The higher the degree of latitude the smaller would be the light intensity.
* The amount absorbed and dispersed by the atmosphere.
* Atmospheric conditions of moisture, clouds, dust, etc. also influence the dispersion of light.
* Topography and landforms of a region
* The type of vegetation

On water bodies the variations in light intensity are caused by:

* The reflection by water,
* Scattering of light by suspended organic and inorganic matter in the world.

Photoperiod

Light is a stimulus received by light receptors like the eye (in animals) and chlorophyll (in green plants). The timing of light received daily and seasonally is called "photoperiod".

Photoperiod influences life cycles, opening and closing of buds and flowers in plants, migration, hibernation and breeding in animals.

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Day-Night and Seasonal Cycles

As the earth rotates on its own axis, the day-night cycle occurs. The activities of many plants and animals are based on this cycle. For example,

* With sunrise many birds start singing and begin their activities.
* Darkness signals the food searching activities of nocturnal animals like raccoons, owls, etc.

Most organisms are adapted to the 24 hour cycle of the earth's rotation. The rhythms set by the 24-hour day-night cycle are called **circadian rhythms.**

The Earth's annual revolution around the Sun, combined with the fact that the Earth's axis is tilted, results in seasonal cycles. During the seasons, the length of day and the length of night change. The growth and maturity of many organisms are affected by these periods, called photoperiods. Many plants, for example will flower only when the night is of a certain length. Many kinds of birds respond to the changing photoperiods also. As the days shorten, they fly south and as the day lengthens, they migrate north to breed.

Seasonal cycles also cause other changes. Temperature changes affect the ability of plants to prepare food. Many shed their leaves and become dormant during the winter months. Animals are also affected by decreased food supplies, as well as shorter days and colder temperatures. Some, like the ground squirrel, adapt by hibernating. Many insects survive only through the eggs they lay for the next generation.

Frogs also aestivate during the hot, summer months.

Influence of day-length on Plants

1. Plants that flower only when exposed to short periods of light are called **short-day** plants.

   Example: Chrysanthemums (bloom in the fall), poinsettias, the cocklebur

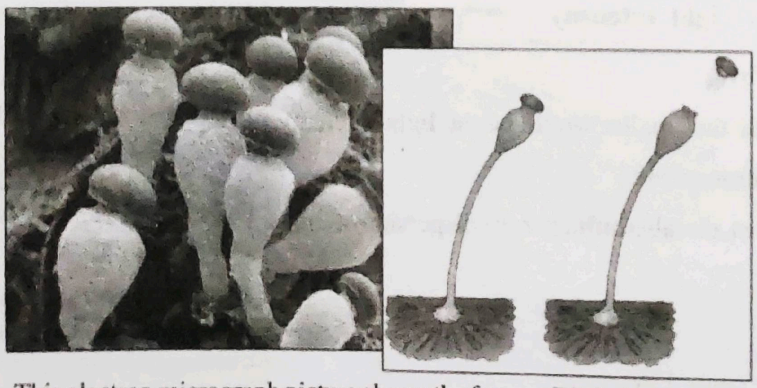
2. Plants that flower only when exposed to long periods of light, are called **long-day** plants.

   Example: Spinach, sugar beets, radish

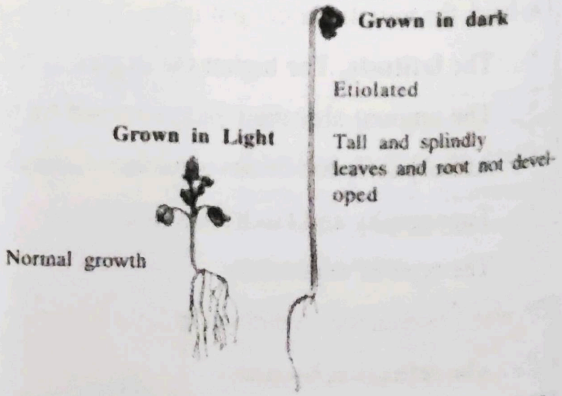
   Note: Spinach and some other members of the group will bloom successfully on a short-day schedule if the night periods are interrupted by a brief exposure to light. They can bloom only if the nights are not too long.

Effect of day-length on spinach, a long-day plant

The plant on the left was grown under short-day conditions, and the one on the right, under long-day conditions.



This electron micrograph picture shows the fungus (Pilobolus) growing on cattle dung. Ripe Pilobolus fruiting bodies bend toward the light and pressure builds up inside. The package of spores blasts off into the air.



The effect of light on the growth of a plant is called photomorphogenesis

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Effect of Light on Plants

1. Light affects photosynthesis in plants
2. Affects production of growth hormones (auxins)
3. Affects growth of tissues, for example, herbs growing in shady places have spongy tissues.
4. Affects synthesis of chlorophyll.
5. Affects leaf structure and distribution of chloroplasts.
6. Affects opening and closing of stomatal pores.
7. Affects transpiration rate.
8. Affects growth and development of flowers, fruits and seeds.

Effect of Light on Animals

1. Affects metabolism, for example, animals living in caves have slow rate of metabolism.
2. Affects reproduction, for example, breeding activities of birds and animals are increased.
3. Accelerates development as in fishes like salmon.
4. Affects development of eyes, for example, nocturnal animals have larger eyes.
5. Affects vision of animals.
6. Affects formation of pigments, for example, skin colour, protective coloration that helps in camouflage.
7. Locomotion is increased in presence of light.

Ecological Relation of Temperature

Temperature plays a very important role in regulating the metabolic processes of living organisms.

Temperature Variations in Ecosystems

The temperature varies greatly in terrestrial habitats and lesser variation is seen in aquatic habitats. For example,

* In a pond, the temperature is never lower than 0°C
* In oceans the temperature is never lower than −2.5°C. Maximum temperature in oceans goes up to 36°C.
* On land the lowest recorded temperature is −70°C (in Siberia). In deserts the temperature may go up to 60°C.

Effect of Temperatures on Plants and Animals

1. Enzymes work best at optimum temperatures. Thus, temperature affects the metabolism of plant and animals.
2. Temperature affects the breeding seasons of animals. Some species breed throughout the year while some breed only in winter or summer.
3. Growth rate and reproduction is affected by temperature.
4. Effect on sex ratio. In certain species temperature affects the egg produced at different temperatures. Under normal temperature the eggs produced may be female and at higher temperature may be male.
5. Temperature affects the life cycle of plants and animals and thus, their survival among various species.

Significance of Photoperiodism

Photoperiodism helps control the flowering of a large number of agricultural and horticultural plants by artificial shortening of day-length (by shading) or lengthening of day-length by electric illumination.

Thus, photoperiodism helps grow plants at seasons where the required day-length is not available under natural conditions.

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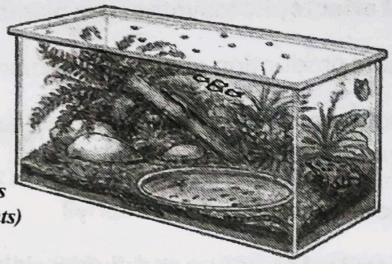
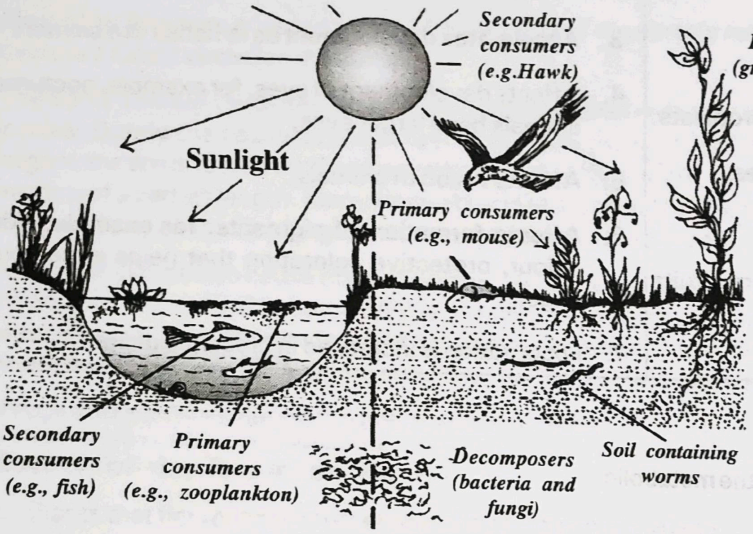
Food Relations in an Ecosystem

An ecosystem is a self sustaining, structural and functional unit of the biosphere. As stated earlier each ecosystem is not closed. **Sunlight** and air enter it, water drains from it, nutrients enter and leave through the soil, and plant seeds and animals come and go.



An aquarium is an artificially created ecosystem



Energy Flow in an Ecosystem

* In any ecosystem, energy flows between living things through various stages or levels. At each level, energy is lost as heat during processes such as movement and breathing.
* Green plants obtain energy from Sun. They prepare food in the form of **carbohydrates** by a process called **photosynthesis.** Some plants like the **Venus flytrap,** and the **Pitcher plant** are carnivorous and feed on insects.
* Animals obtain food from plants - directly or indirectly by eating animals that feed on plants.
* **Food chains** describe these patterns in the feeding relationships.
* Since plants and animals are usually eaten by more than one organism, ecologists tend to describe the energy flow between plants and animals in terms of a series of related food chains or a **food web.**
* The number of living things occupying a given habitat depends mainly on the amount of food available to them and the competition for that food.

  As the amount of available energy decreases through the feeding levels, there are fewer and fewer individuals at each consecutive level.

  For example, in a meadow, there are many plants, plenty of **herbivores**, a few **carnivores**, and only a few 'top' carnivores. This numerical relationship is also called a **'food pyramid'.**

Terms to Note

1. **Producers:** Green plants (or plants containing chlorophyll), which are the food source of many organisms, are said to be **producers.**

   Plants are also called **autotrophs** since they synthesize their own food.

2. **Consumers:** These consist of animals that cannot manufacture their own food and so depend on continued supplies of ready-made food substances usually from plant sources for their energy and growth.

   There are at least two levels of consumers in an ecosystem:

   (i) **Primary Consumers:** These consist principally of animals (known as *herbivores*) which feed directly on plant materials.

   Example: Sheep, goats, squirrel, caterpillar

   (ii) **Secondary Consumers** *(lower carnivores)*: These are animals which derive nutrition from other animals.

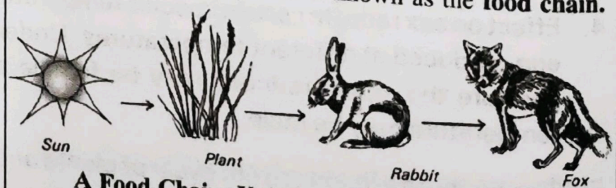
   Example: Fox, wolf

   A secondary consumer may itself be eaten by yet another animal (a tertiary consumer).

   Example: Lion, leopard etc.

3. **Decomposers:** They are chiefly the soil microorganisms, such as bacteria and fungi as well as earthworms, beetles and mites. Their function is to decompose the organic compounds in the bodies of dead producers and consumers.

The sequence of events which show an ultimate dependence of animals on plants is known as the **food chain.**



A Food Chain: Unidirectional flow of Energy

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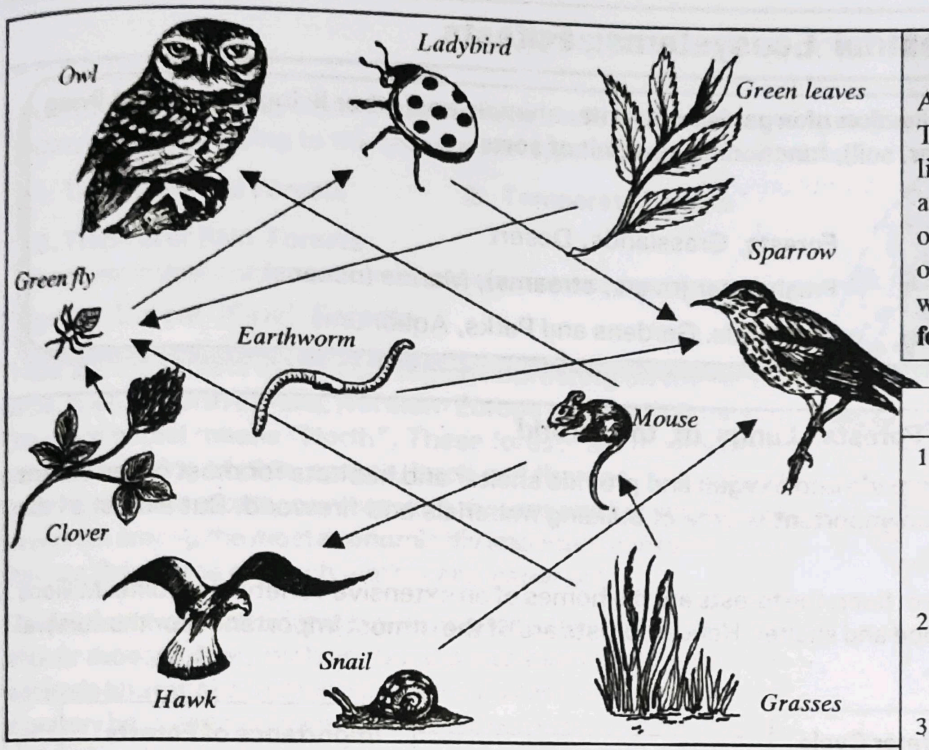


Food Web

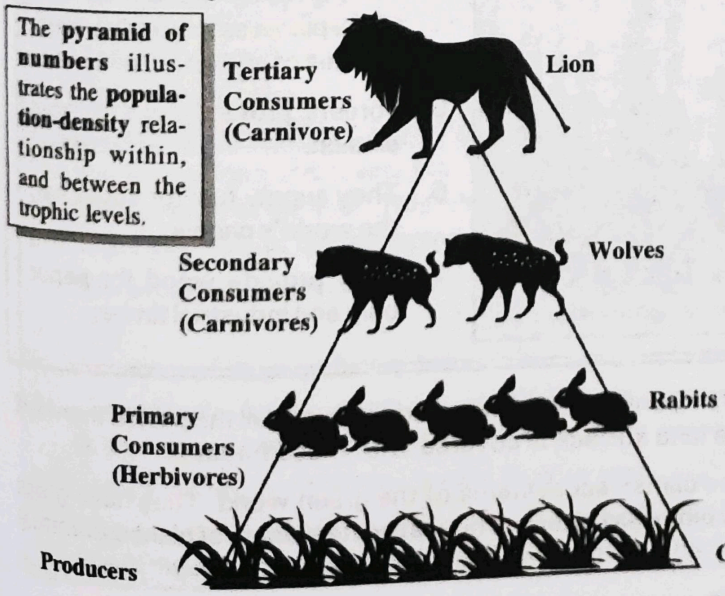
A food chain does not operate in isolation. There exists a network with intercrosses and linkages that characterises any ecosystem, be it a grassland, a crop field, a pond or the ocean. In other words, in a biosphere many food chains operate simultaneously forming a complex network. Such a network of food chains is called a **food web.**

Food Chain	Food Web
1. The sequence of living organisms in which one consumes another to transfer food energy.	It is a network of food-chains forming relationships between various organisms.
2. Each organism occupies only one trophic level at a time	Each organism occupies different levels simultaneously.
3. A food chain always begins with a green plant.	It has many linkages starting with different organisms.

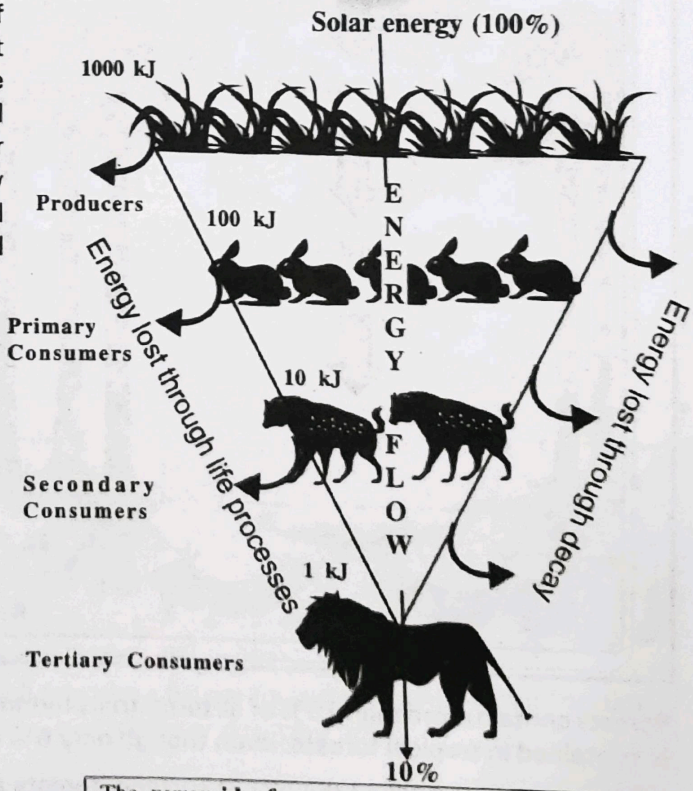
Pyramid of Numbers and Pyramid of Energy

It is seen that the **number** of individuals **decreases** with the rise in trophic levels. This happens due to differences in population growth rate and also the predation upon smaller individuals by larger ones.

Energy also follows a similar pattern. To begin with, the leaves of green plants are able to use only about 1-3% of the light energy that reaches them from the sun while the rest escapes as heat. The energy absorbed is converted by photosynthesis into the potential energy of a food substance. Again, when the primary consumer (herbivore) eats a plant material, only a fraction of the energy stored in the plant is used to form the protoplasm of the animal while the greater part of it is lost as heat. The process is repeated thereafter with higher levels of consumers.



The **pyramid of numbers** illustrates the **population-density** relationship within, and between the trophic levels.



The **pyramid of energy** illustrates the relationship between the **amount of energy available** and the corresponding trophic level of a food chain.

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Terrestrial Ecosystems: Forests

An ecosystem is a naturally occurring collection of organisms (plants, animals and other living organisms) living together with their environment (air, water, soil), functioning as a unit of sorts.

The following ecosytems are recognised:

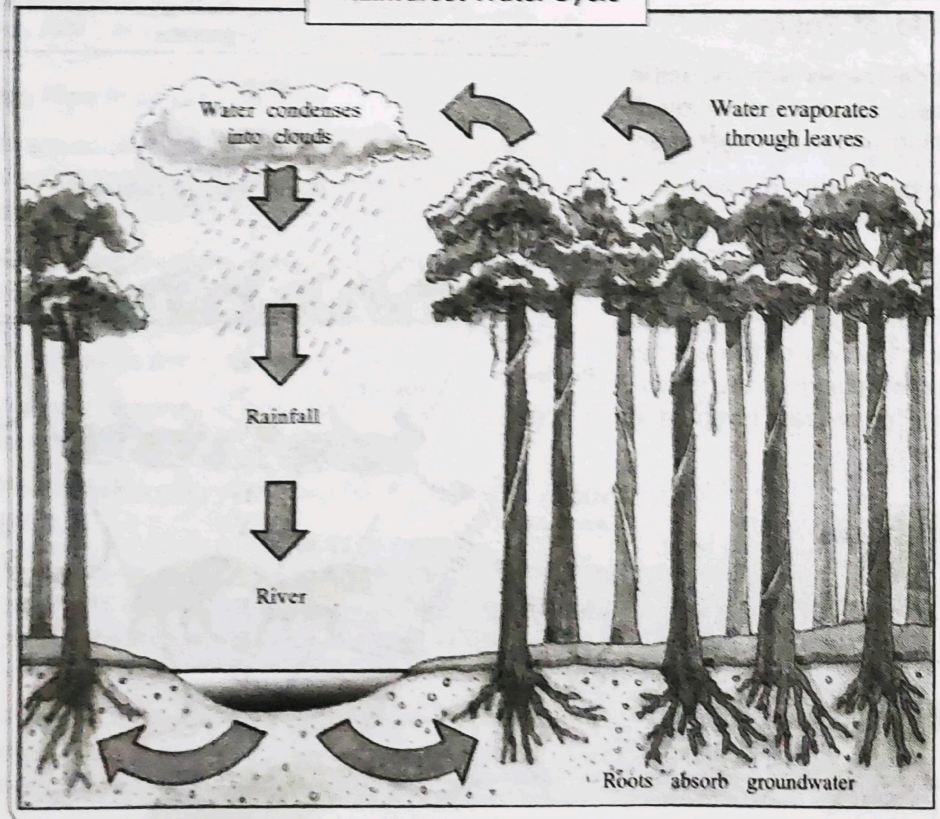
1. Terrestrial Ecosystems	Forests, Grasslands, Desert
2. Aquatic	Freshwater (rivers, streams), Marine (oceans)
3. Artificial (man-made)	Croplands, Gardens and Parks, Aquariums

Forests: Lungs of the World

Forests, like the oceans recycle carbon dioxide into oxygen and provide shelter and habitats for most of the worlds diverse living organisms. They are also an important source of building materials and firewood. But almost all the forests of the world are under threat.

From the tops of the trees to the leaf system floor, the forests are the homes of an extensive variety of wildlife. Millions of living organisms rely on the trees for food and shelter. Hence, forests are of the utmost importance for the survival of countless species of living organisms.

Rainforest Water Cycle



Importance of Forests

Forests are power houses of many basic biological processes, for example:

1. Photosynthesis, biological growth, creation of fertile humus and transfer of energy.
2. Forests help to determine temperature, rainfall and other climatic conditions.
3. They are the fountainheads of rivers.
4. They are major gene reservoirs of our planet as they house major species of all living organisms.
5. Forests protect the soil from erosion.
6. They supply fuel for about half the world's people.
7. They provide wood for paper pulp and industrial timber.

Forests contain more than 75% of all terrestrial phytomass (amount of dry plant material). Out of all this, more than half is contained in tropical forests, even though only 6% of the land surface is covered with these forests.

Occupying about 30% of the planet surface, forests are the climax ecosystems of the green world. They have great stocks of biomass (dry plant and animal matter), produce new biomass faster and house greater variety of plant and animal species than any other ecosystem.

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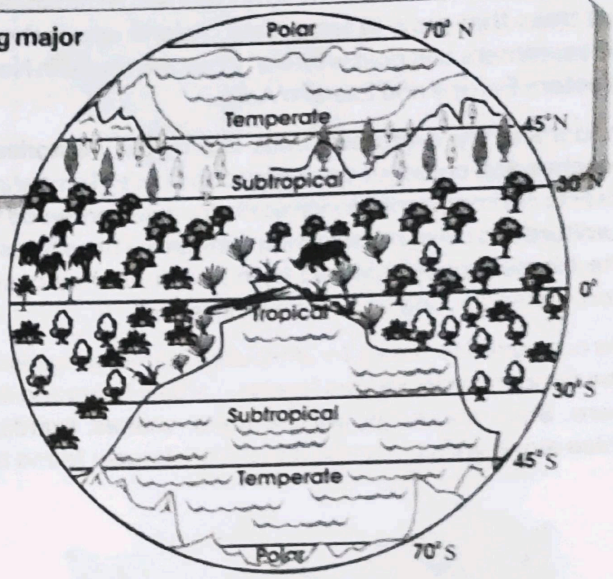
Classification of Forests

Forests can be broadly classified into three kinds of forests forming major ecosystems according to the climate and type of trees.

1. **Taiga or Boreal Forests**
2. **Temperate Forests**
3. **Tropical or Rain Forests**



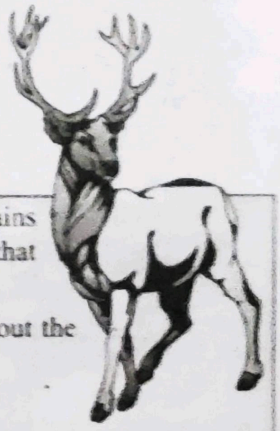
Taiga or Boreal (Pine) Forests

These are the forests in the cool regions bordering on the Arctic circle, such as north of Asia, Northern Europe and North America. The word boreal means "North". These forests are mostly **evergreen** comprising of **pine, spruce, larch and fir trees.** The ground under the trees is mostly covered with **mosses and lichens. Boreal forests are among the most economically important ecosystems as they are the source of much lumber and paper pulp.**

The dominant animals of this biome include a few large mammals **(elks or moose, deer, wolves, pumas and bears)**, small rodents **(squirrels and rabbits)**, small carnivores **(foxes)**, many **insects** and **migratory** birds especially **water fowl** and carnivorous birds such as **owls and eagles.**

Fires, storms and outbreak of insects are common occurrences in these forests. Another common feature of these forests is the presence of the numerous lakes.

Poplar Spruce



The winters are long and severe but in the forest the soil is loosely packed. The soil surface remains unfrozen for most of the year. This allows animals to burrow for the winter in comfort and ensures that insects are available to the insectivores.

1. The evergreen conifers guarantee a continuous food supply of seeds, twigs and buds throughout the year.
2. Members of the deer family feed on low growing vegetation and mosses and lichens.
3. Carpeting the forest floor is a layer of fallen pine needles which provides a habitat for carpenter ants, carabid beetles and spiders. Other spiders construct webs under loose barks on tree trunks or decaying timber.
4. Rotten wood is a home for insects such as ants.
5. The common predators are the sable and weasels which hunts hares, the **brown bear** and the **wolves** which prey on deers. Small mammals, birds and fish fall prey to the **eagle.**

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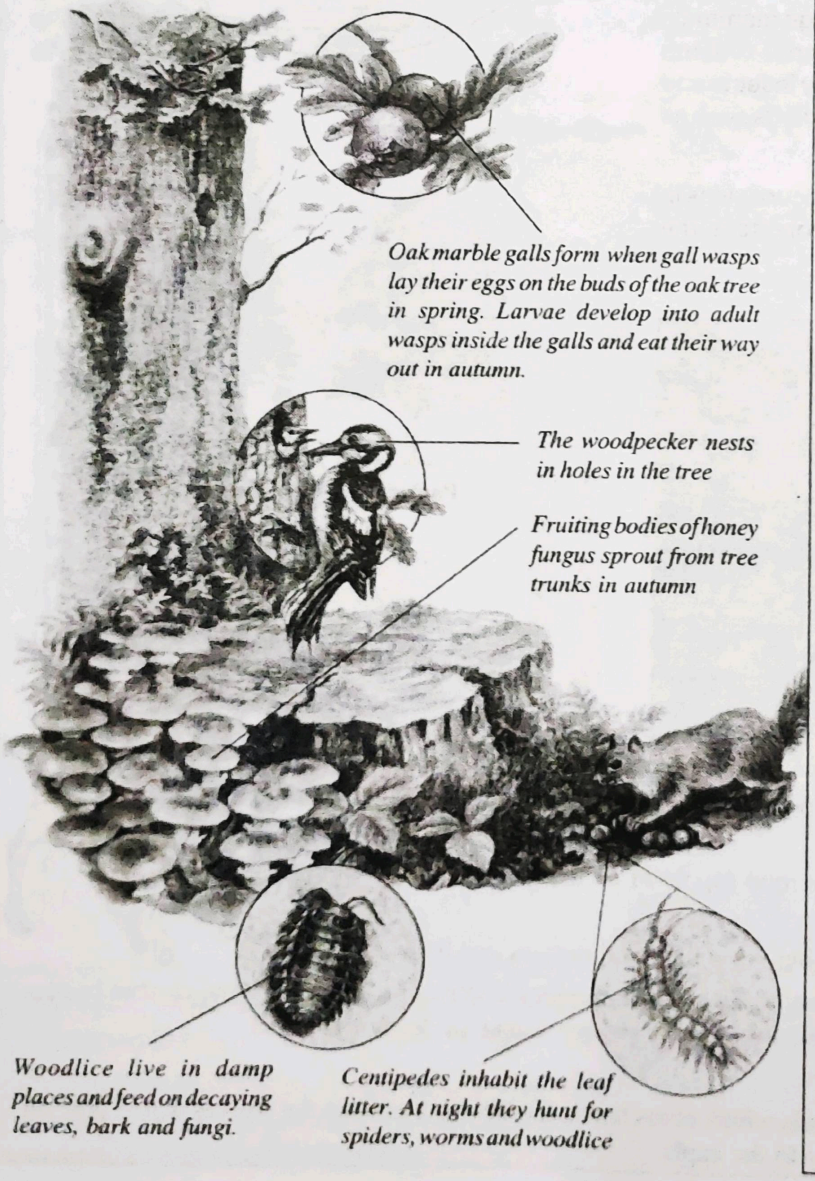
Temperate Forests (Woodlands) or Chaparral

These forests are more diverse and consist of broad-leaved deciduous trees that grow in temperate regions where there are warm, wet summers and cold winters. They are found in North America, Western Europe and Eastern Asia.

Predominantly evergreen trees like **maple, hickories, oak, elms, beeches and chestnut trees** are found here. Temperate deciduous forests are important economically for their **hardwood trees used for furniture** and other **construction materials.** These forests are among the biomes most changed by humans as they occur in regions dominated for long by human civilisation.

As compared to Boreal forests, large mammals are less **common in the temperate deciduous forests. Largely** bears and deer are found here. **Squirrels, frogs, salamanders, snakes, lizards, rabbits** and **mice** along with **birds** and **insects** are largely found here.

Oak tree



Oak marble galls form when gall wasps lay their eggs on the buds of the oak tree in spring. Larvae develop into adult wasps inside the galls and eat their way out in autumn.

The woodpecker nests in holes in the tree

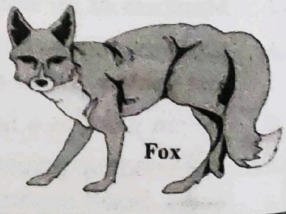
Fruiting bodies of honey fungus sprout from tree trunks in autumn

Woodlice live in damp places and feed on decaying leaves, bark and fungi.

Centipedes inhabit the leaf litter. At night they hunt for spiders, worms and woodlice

Trees in temperate forests are generally smaller than those of tropical forests. Where there is enough light, there may be an undergrowth of even smaller trees. Below this is a ground layer of herbaceous plants which must complete their life-cycle in the spring months, that is, before the trees and underwood are in full leaf and shut out the sunlight.

1. The deer (elk, moose) is now the largest animal in the woodlands. The largest European animals the aurochs (a species of the wild-ox) became extinct in the 17th century. The wood bison has also been reduced in number and range by humans.
2. The common oak tree supports a wealth of small animal life. In the spring, swarms of caterpillars, bugs and beetles feed on the new leaves. The tree compensates this loss by putting out a late growth called "lammas leaf".
3. Insect larvae live in twigs, dead wood, galls and in acorns.
4. The forest floor supports a micro-community. These microscopic organisms (decomposers) constantly break down the dead tissues of the forest litter and return the components to the soil for reuse by the plant.
5. In the soil beneath the tree, a variety of worms and larvae feed on soft, rotting plants and roots.
6. The tiny creatures are the prey of hunters like beetles and slimy salamanders. The larger animals are taken by birds and forest mammals like foxes and badgers.



Fox

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Tropical or Rain Forests

Tropical rain forests are located in the equatorial regions, primarily in South and Central America, North-Eastern Australia, Congo River Basin of Africa, Indonesia, Philippines, Hawaii and parts of Malaysia and India, these forests cover about one-twelfth of the Earth's surface but contain more than half of the Earth's flora and fauna. These regions are warm and wet with over 2000 mm of rain annually. Average temperature is about 27°C. This is why thousand of species are found here.

The trees are **broad leaved** and **evergreen** such as Brazil nut, rubber, mahogany, ebony, palm, etc. Rainforest trees are covered with **epiphytes** – plants whose roots never reach the soil but take water from the air.

Most tropical rainforests have several layers. High above the main forest are tall trees up to 60 m tall. Below these, about 30-50 m above the ground is a dense canopy of leaves and branches of tall trees. Below this layer are small conical trees and a huge range of shrubs. Clinging **lianas** wind their way up through the trees where they are able to get sunlight.

The way in which the forest is formed into well-defined layers means that animals can live and feed on different habitats at different heights from the ground. The whole forest is a finely balanced ecosystem where the animals feed not only in different layers but also at different times. Monkeys and birds are diurnal, but most forest mammals are nocturnal.

Monkeys and **squirrels** are the most agile tree-top dwellers. The vegetarian gorillas, although they can climb trees, prefer to pick leaves from ground vegetation. These animals, along with the forest elephants, buffalo and okapi are among the few large terrestrial mammals of the rain forest.

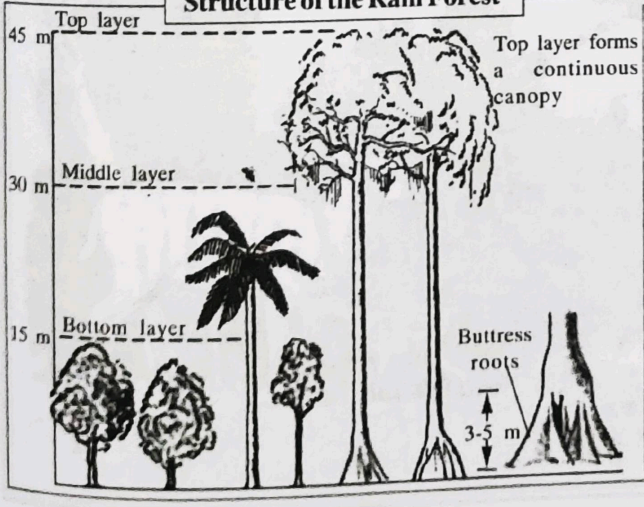
While herbivores remain rigidly within a layer, predators are forced to make journeys from the ground to the canopy in search of bird, small mammal and insect prey.

A typical rain forest

Broad leaves of the philodendron

Lianas, or bush ropes, hang down from the rain forest canopy.

Structure of the Rain Forest



1. The **emergent layer** has the tallest trees such as **kapok** and **mahogany** which sometimes tower over 50 m. The trees of this layer are widely spaced. Their seeds are dispersed by wind.
2. The **canopy** is the next layer. It is formed by the crowns of trees, often forming several tiers of vegetation. This layer is very crowded and blocks out most of the sunlight and wind. Since these trees grow very quickly towards the light, they tend to have straight trunks with few branches. Their seeds are dispersed by animals.
3. The next layer is the **understory**. Not much light reaches this layer. The air is still, damp and humid. The plants in this layer have large leaves to maximize the light absorbed.
4. The **forest floor** has plants with leaves arranged in rosettes so that the upper leaves do not shade the lower ones. Ferns have divided fronds to get maximum light.

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Points to Remember

(i) Each feeding layer is known as a **trophic level.**

(ii) The energy flows from the sun through to the ultimate consumer in a **single direction.**

(iii) The decreasing energy level at each step limits the trophic level to four, or at the most, five. (Some of the energy is changed to heat or used in growth).

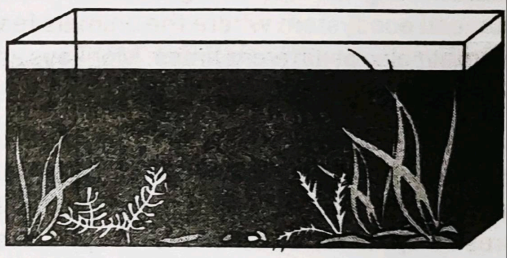
(iv) The total dry weight of organic matter of all organisms combined together at any trophic level is called **biomass.**

(v) Maximum energy is available at the lowest level. Hence plants and herbivores get more energy rich food than those organisms at the third, fourth or fifth levels.

(vi) At every successive trophic level, there is a **loss of energy,** but **no loss of nutrients.** This is because the nutrients in the body of the organism is released and **recycled** when the organism dies and is subject to **decomposition.**

Exercise

1. **Answer the following questions:**
   - (i) Define ecosystem and name the central role that autotrophs play in all ecosystems.
   - (ii) Define and give examples of trophic levels in ecosystems.
2. The diagram alongside shows a closed ecosystem in an aquarium.
   - (i) What is the fish's food?
   - (ii) What is the snail's food?
   - (iii) What happens to the waste and dead material in the jar?
   - (iv) Fish and snails need oxygen to breathe? Why is a pump to supply air containing oxygen not necessary?
   - (v) What could cause the system to fail?
   - (vi) Green plants need carbon dioxide to make food. From where are the green plants in the above system getting carbon dioxide?



3. In the meadow ecosystem shown alongside, what are the examples of producers and primary consumers? What are some of the higher-order consumers that might also be a part of this community?

4. Explain the difference between Habitat and Niche. Describe the niche of a plant or animal in your region.
5. Trees are important in maintaining environmental balance. Discuss the value of forests with respect to -
   - (i) Control of soil erosion and maintaining fertility.
   - (ii) Recycling of water.
   - (iii) Protein conservation.

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6. Choose the correct answer from the options given below:

(i) Match the ecosystem terms with the suitable description.

Primary producers; Consumers; Decomposers; Detrivores

a. Herbivores, carnivores, omnivores, parasites.

b. Feed on partly decomposed organic particles.

c. Break down remains or products of other organisms.

d. Photoautotrophs

(ii) Match the ecosystem terms with suitable description.

Nitrogen availability; Ecosystem components; Phosphorus; Ammonium; Biogeochemical cycle

a. Movement of water or nutrients from the environment to organisms and back.

b. Form of nitrogen plants can take up.

c. Key limiting factor for net primary production in land ecosystems

d. Producers, consumers, detritivores decomposers.

e. Moves through a sedimentary cycle.

7. In nature, most organisms eat, or are eaten, by several different kinds of other organisms. Study the food relation shown in the illustration and answer the following questions:

(i) Name and define the type of food relation shown here.

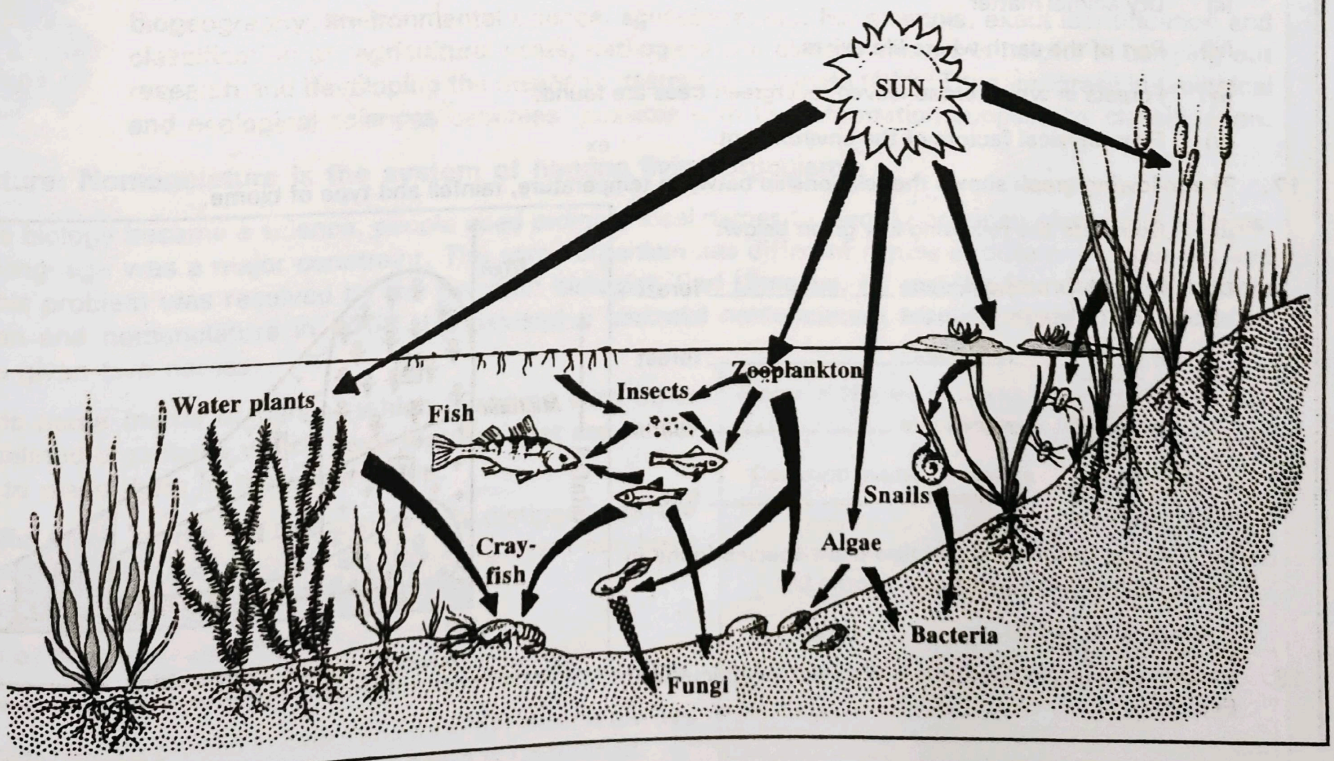
(ii) Identify the decomposers and state their role.

(iii) Give a term that describes the following members of the food relation:

Green plants, crayfish, snail, insects, bacteria, zooplankton.

(iv) State the role of the Sun.

(v) Name any three abiotic factors essential to the biotic components shown in the illustration.



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8. **Explain the difference between the following pairs:**

   (i) Food chain and food web

   (ii) Habitat and niche

   (iii) Structural and Functional Components of an ecosystem

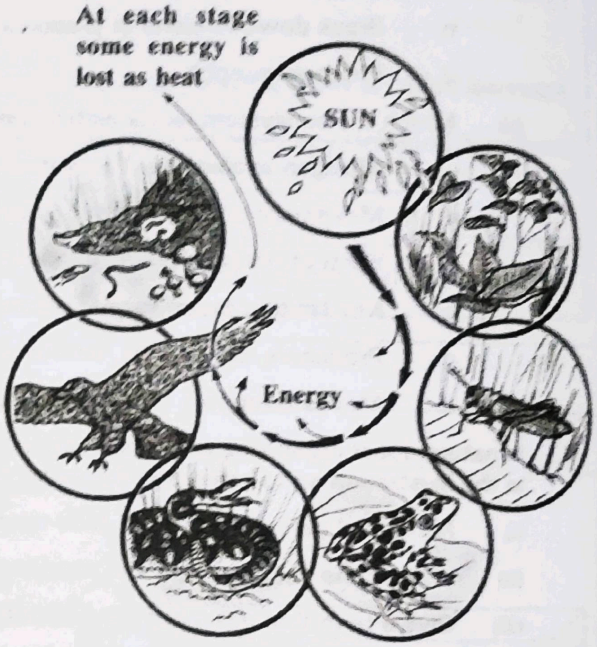
   (iv) Microconsumers and Macroconsumers

9. As one organism eats another, only a part of the energy stored in the organism being eaten is later stored in the body of the "eater". Most of the energy is "lost" or given up to the environment as heat.

   (i) Why do you think this happens?

   (ii) Name and state the law that accounts for the energy flow within each food chain.

   (iii) Explain why: Shorter the food chain, greater is the energy advantage, or a food-chain cannot have more than six steps.



10. Draw a food chain or web of the following organisms – honey sucker flower, robin, butterfly, flea, cat and microorganisms.

11. Name two biotic and four abiotic components of an ecosystem.

12. Which life forms would be most abundant in a food web – Producers, primary consumers or secondary consumers? Explain.

13. Explain why pyramids of biomass are pyramid shaped, rather than another shape, such as a square.

14. State three effects each, of light on survival of plants and animals.

15. Differentiate between physically dry and physiologically dry soils.

16. Name the following:

   (i) A naturally occurring collection of organisms (plants, animals, etc.) living together.

   (ii) Dry animal matter

   (iii) Part of the earth where life exists.

   (iv) Forests in which broad leaved, evergreen trees are found.

   (v) Four physical factors of the environment.

17. The following graph shows the relationship between temperature, rainfall and type of biome.

   (i) Complete the following key given below:

   A [ ] represents _____ forest

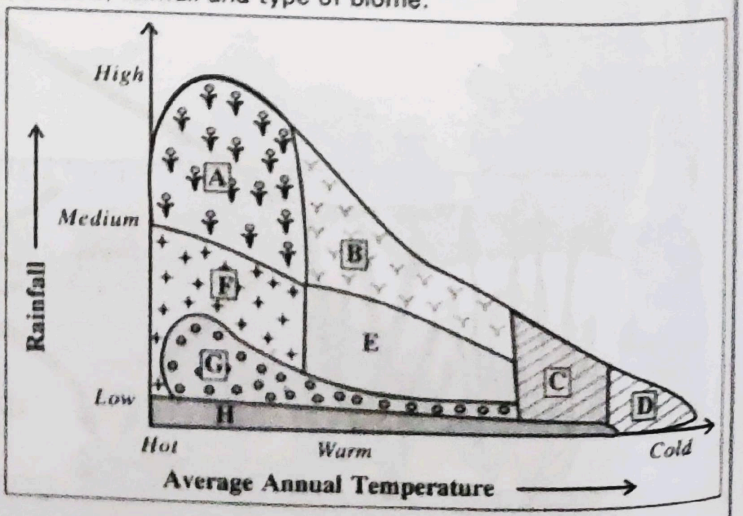
   E [ ] represents _____ forest

   H [ ] represents _____ biome

   D [ ] represents _____ forest

   (ii) Name two animal and two plant species found in each of the regions represented by:

   A, E, H and D



18. Would Tropical rain forests be well suited for agriculture? Explain.

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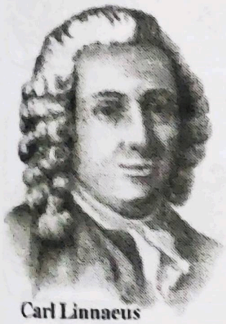
9
Animal Classification

Introduction

We exist in the midst of more than a million different life forms. The oldest forms of life are the fossils of simple bacteria and algae, over 3.5 billion years old. Today there are more than 2 million living organisms on Earth and every organism of the living world is unique in itself. This uniqueness of individuals is the diversity in life forms. Our interest in these life forms stems from the fact that our very existence depends on them.

- The flora and the fauna are the source of our food and clothing.
- They help to maintain the ecological balance.
- Many of the plants and animals are items for trade and commerce.
- A knowledge of these organisms also provides a clue to our own origin.

Thus, in order to carry out a systematic study, it is important that the multitude of life forms are grouped in a convenient manner such that maximum information about them can be obtained with the least effort. Moreover, availability of information leads to efficient predictions.


Carl Linnaeus

Taxonomy: Taxonomy is the science that deals with the classification of living organisms.

The ultimate object of classification is to arrange organisms in a way such that we gain an idea about the sequence of their origin and evolution from simpler, primitive types, to more complex advanced types. Thus, a **genetic relationship** is established.

The science of classification enables us to use this information in other disciplines like biogeography, environmental science, agriculture, etc. For example, exact identification and classification of agricultural pests, pathogens and disease vectors is helpful in carrying out research and developing the means to destroy or eliminate them. Thus, progress in biological and ecological sciences becomes possible with the information supplied by classification.

Nomenclature: Nomenclature is the system of naming living organisms.

Long before biology became a science, people used ordinary local names to identify common plants and animals. However, language was a major constraint. The same organism has different names in different languages and dialects. This problem was resolved by the Swedish biologist, **Carl Linnaeus.** He laid the foundation of modern classification and nomenclature in **1758.** He devised a binomial nomenclature (naming system) in which an organism is given two names:

a. A **generic name** (name of genus) which it shares with other closely related organisms which have features that are similar enough to place them in the same group.

b. A **specific name** (name of species) which distinguishes the organism from all other species. No other organism can have the same combination of genus and species.

Convention of Nomenclature

1. Genus is always written first with the initial letter in capital.
2. The species name is printed in italics and its initial letter is always small. When hand-written, the species name is underlined.

Binomial Names of Some Common Plants and Animals

	Common name	Genus	Species
1.	Shoe flower (china rose)	*Hibiscus*	*rosa sinensis*
2.	Humans	*Homo*	*sapiens*
3.	Banyan	*Ficus*	*begalensis*
4.	Cat	*Felis*	*domesticus*
5.	Frog	*Rana*	*tigrina*

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Units of Classification

Grouping living organisms together by similarities, shows how one group is related to another and how modern organisms may have evolved. Each organism can be placed in levels, starting with the largest group-kingdom, then by phylum, class, order, family, genus and lastly by species.

1. **Kingdom:** All living organisms are arranged into a broad comprehensive unit called **kingdom**. The kingdom is the largest division of living things. There are **five kingdoms.**

   Example: *Plant kingdom, Animal kingdom, the Fungi kingdom, the Protist kingdom and the Moneran kingdom.*

2. **Phylum or Division:** Within each kingdom there are different groups related by common characteristics. These constitute a phylum (in animals) or division (in plants).

   Example: *All animals which have a notochord present in the embryo belong to the phylum* ***Chordata.***

3. **Class:** Members of a phylum or division related to one another by common characteristics make a class.

   Example: *Chordates like dogs, cats, bats, dolphins, monkeys are classed as* ***mammalia.*** *They are all characterised by a hairy exoskeleton, milk glands, external ear, etc.*

4. **Order:** Members of a class that share common characteristics constitute an order.

   Example: *A tiger (Panthera tigris) and a wolf (Canis lupus) share the common characteristic of possessing jaws with powerful incisors and large, sharp canines adapted for flesh-eating. Hence both are placed in the order* ***Carnivora.***

5. **Family:** Members of the same order which show **general structural resemblances** to one another are placed in the same family.

   Example: *A cat and a lion belong to the "cat" family Felidae. Both possess similar structure and have retractive claws.*

   Note: A dog does not belong to the same family as the cat because it does not have retractive claws.

6. **Genus:** Members of the same family which resemble each other in their **reproductive organs** form the genus.

   Example: *Banyan and fig differ in vegetative characters like shape, size and surface of leaf, but resemble in their reproductive organs such as inflorescence, flower, fruit and seed. Thus, both belong to the genus Ficus.*

7. **Species:** Species is the fundamental unit of classification. It is composed of individuals which can interbreed to produce a progeny (offspring) of the same kind, which in turn is capable of reproducing its own kind. Individuals of the same species resemble each other closely structurally and functionally.

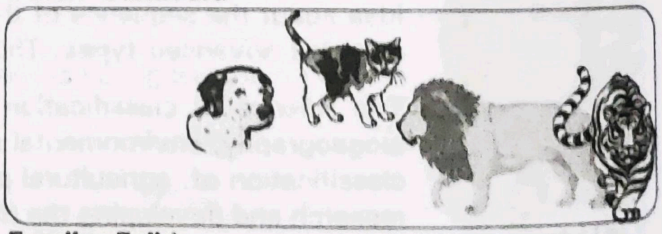
Note: Several intermediate steps in classification are inserted to clarify complex plant or animal relationships such as sub-division, sub-class etc.

Kingdom: Animalia

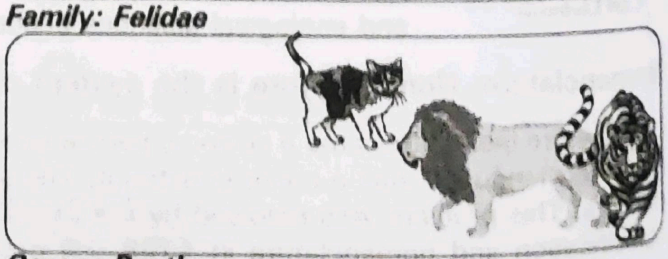
Phylum: Chordata

Class: Mammalia

Order: Carnivora



Family: Felidae



Genus: Panthera

Species: tigris

Interbreeding between different species

When a **horse** (*Equus cabalus*) and **ass** (*Equus asinus*) belonging to different species interbreed, the product is the **mule** which is sterile i.e., incapable of reproducing.

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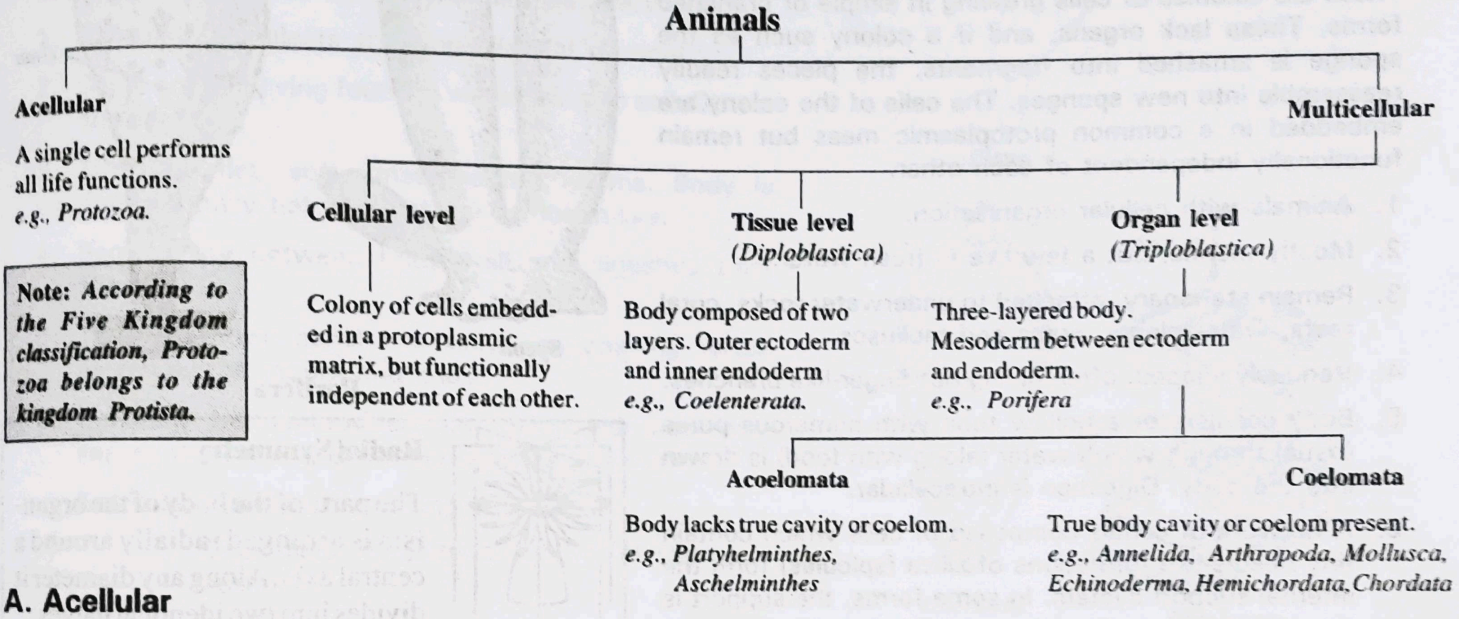
Animal Classification

Approximately 2000 million years ago, the first animal appeared in the waters of the Earth. Since then, millions of animals have evolved. In a manner similar to that of plants, these myriad forms have been classified by scientists according to their complexity, on the assumption that the complex animals evolved from the simpler ones. The basic structure of the classification is given below:



Note: ***According to the Five Kingdom classification, Protozoa belongs to the kingdom Protista.***

A. Acellular

The simplest and probably the first animals to appear on the surface of earth were the single-celled protozoans.

Characteristics of Phylum Protozoa

Protozoa may be free-living or parasitic. Parasitic protozoans cause disease in the host animal. Nutrition is **heterotrophic** and reproduction is through **binary fission** or **multiple fission** and **conjugation**. The **four** types are:

1. **Flagellate:** These locomote or propel themselves by means of whip-like processes called **flagella**.

   Example: ***Trypanosoma: parasitic, lives in the blood stream of humans and causes sleeping sickness.***

2. **Ciliates:** These locomote by means of a large number of fine hair-like growths called **cilia**.

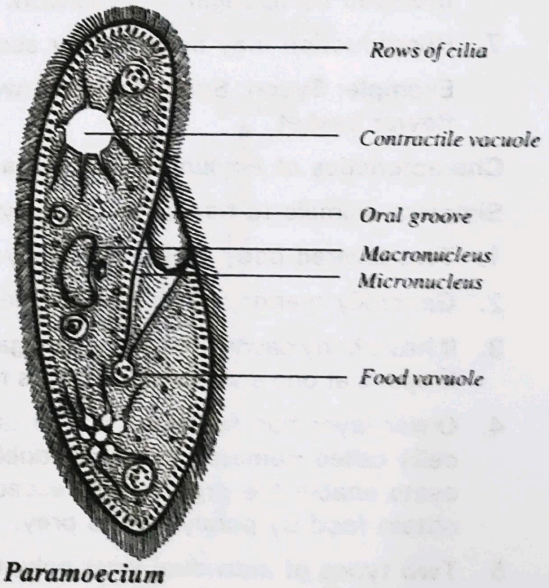
   Example: ***Paramoecium***

3. **Rhizopods:** These have no definite shape. They extend their jelly-like body in any direction (pseudopodia) to engulf food or to move.

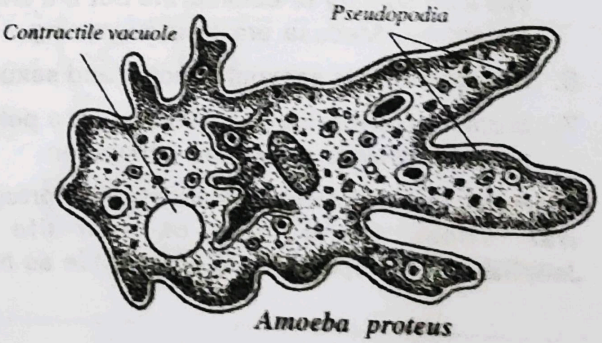
   Example: ***Amoeba, Entamoeba hystolytica*** **(it causes amoebic dysentery).**

4. **Sporozoans:** Spore producing, internal parasites with complex life cycles. A generation reproducing sexually may give rise to an asexual generation in a different host.

   Example: ***Plasmodium (causes malaria).***



Paramoecium



Amoeba proteus

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B. Multicellular

The development of multicellular forms with a true tissue system, is foreshadowed by **colonial protozoans** which form the **phylum porifera.**

Characteristics of Phylum Porifera

These are colonies of cells growing in simple or branched forms. These lack organs, and if a colony such as the sponge is smashed into fragments, the pieces readily reassemble into new sponges. The cells of the colony are embedded in a common protoplasmic mass but remain functionally independent of each other.

1. Animals with cellular organisation.
2. Mostly marine, but a few live in fresh water.
3. Remain stationary, attached to underwater rocks, coral reefs, water plants, crabs and molluscs.
4. Variously shaped, often giving out finger-like branches.
5. Body consists of a hollow tube with numerous pores (ostia) through which water (along with food) is drawn into the body. Digestion is **intracellular.**
6. A network of canals composed of cells which contain tiny needle-like formations of silica **(spicules)** form the internal support system. In some forms, the support is provided by **spongin**, a framework of elastic fibres.
7. Reproduction may be sexual or asexual by budding.

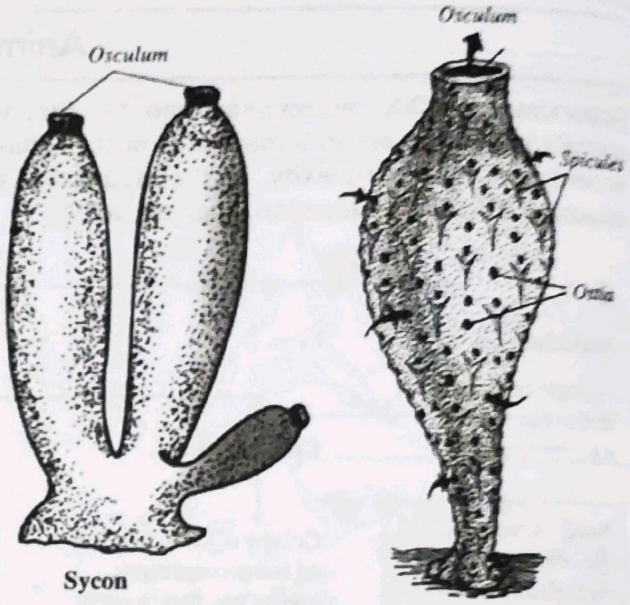
Example: Sycon, Spongilla (fresh water sponge) Venus flower basket

Characteristics of Phylum Coelenterata (Cnidaria).

Simplest animals to have a nervous system and gut.

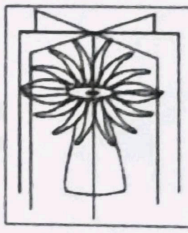
1. Two-layered body which is **radially symmetrical.**
2. Generally marine, but a few species are fresh water.
3. It has a body cavity (coelom) called **gastrovascular** cavity. It opens at one end which serves as the mouth and anus.
4. Outer layer has **tentacles** and is armed with stinging cells called **nematocysts** or **cnidoblasts.** The nematocysts enable the organism to escape danger and also obtain food by paralysing its prey.
5. Two types of individual exist-**polyps** and **medusa.** Polyps lead solitary or colonial life but are always fixed or sedentary. Medusa are free swimming.
6. Reproduction is **asexual** in polyp and **sexual** in medusa.
7. In colonial forms, life-cycle consists of a **polyp** generation alternating with a **medusa** generation.

Example: Sea anemones, corals, hydra, Portuguese man-o' war. These spend most of their life as polyps. **Jellyfish:** These spend most of their life as medusa.



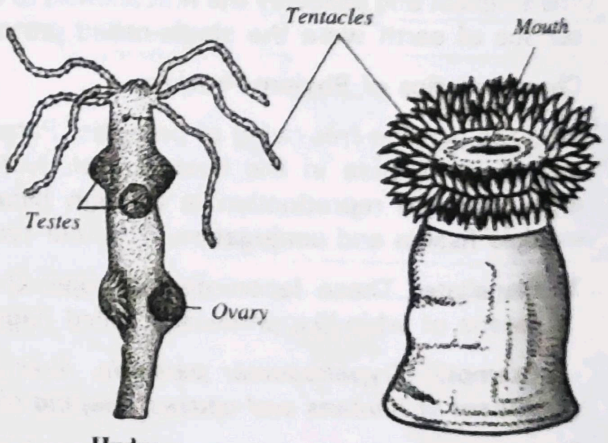
Sycon

Porifera



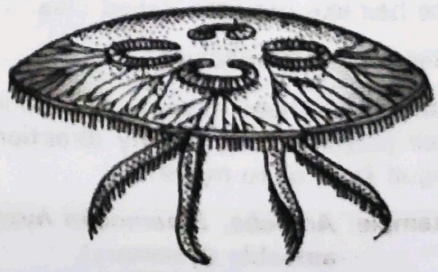
Radial Symmetry

The parts of the body of the organism is arranged radially around a central axis. Along any diameter it divides into two identical halves.



Hydra

Sea anemone


Jellyfish

Note: Corals are protected by chalk skeletons. The skeletons remain when the polyps die, forming reefs in tropical seas.

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The simplest among the triploblasts are the **soft-bodied worms**. These have no true body cavity, respiratory system or blood. They possess a rudimentary nervous system. The mesoderm forms muscles, reproductive organs, and a type of connective tissue called **parenchyma**, which fills up the body cavity. Hence, there is no true coelom.

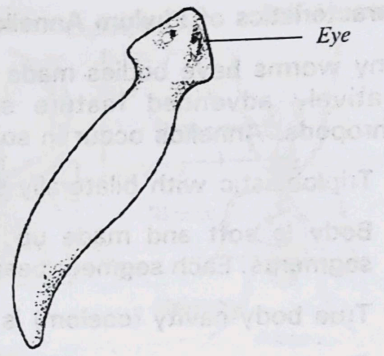
Characteristics of Phylum Platyhelminthes *(platy = flat)*

1. Simplest triploblasts showing bilateral symmetry.
2. Some are free-living found in water or damp soil. Others are parasitic.
3. They are flat, soft, unsegmented worms. Body is dorsoventrally flat and leaf-like or ribbon-like.
4. Body cavity between body wall and digestive tract absent.
5. The alimentary canal has only one opening which serves as the mouth and anus.
6. Generally **hermaphrodites,** i.e., each individual possesses the male and female reproductive organs.

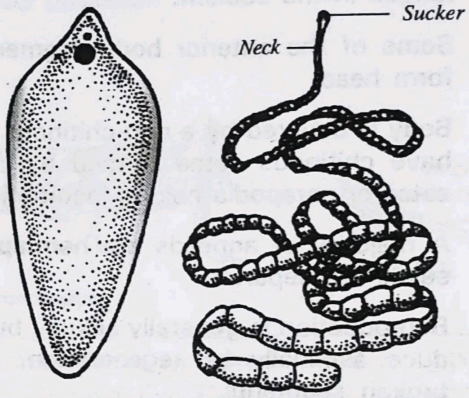
Example: ***Planaria:*** Free living in water.

Liver fluke: Parasite in the liver of sheep, cattle.

Tapeworm: Parasitic in the human intestines. It lacks a digestive tract.



Planaria



Liverfluke *Tape worm*

Platyhelminthes

Characteristics of Phylum Aschelminthes (Nematodes)

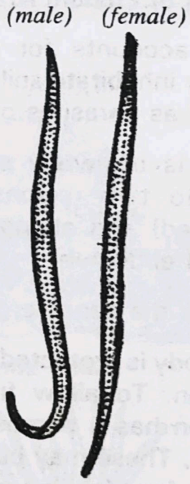
1. Triploblastic body shows bilateral symmetry.
2. Free living or parasitic.
3. Possess long, smooth cylindrical unsegmented body.
4. False body cavity present.
5. Alimentary canal passes through the body from the mouth to the anus.

Example: ***Hook worm and Ascaris:*** Parasites in humans.

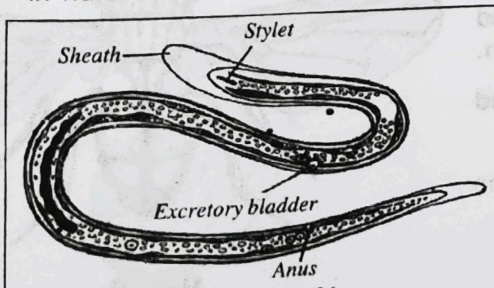
Eelworm: Potato parasite.

Hairworm: Larvae are internal parasites of insects and crustaceans. Adult is free-living.

Wuchereria bancrofti: Parasite, causes filaria in humans.



Ascaris



Wuchereria bancrofti

An extreme case of elephantiasis (filaria)

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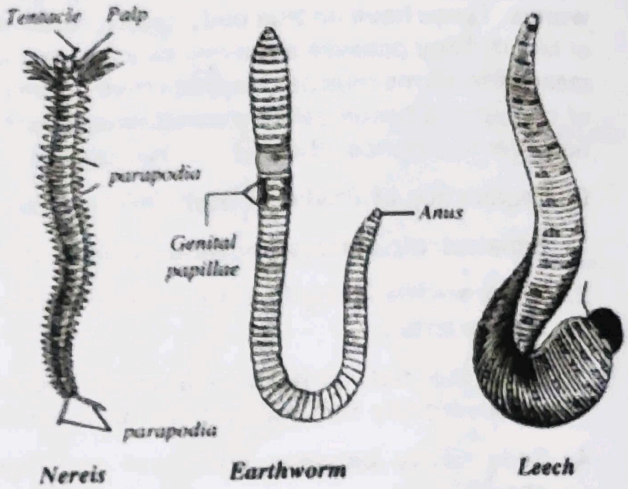
Characteristics of Phylum Annelida

Many worms have bodies made up of segments, a comparatively advanced feature shared by annelids and arthropods. Annelids occur in soil, fresh water and sea.

1. Triploblastic with bilaterally symmetrical bodies.
2. Body is soft and made up of a number of ring-like segments. Each segment bears its own set of muscles.
3. True body cavity (coelom) is present.
4. Organs of excretion (**nephridia**) are segmentally arranged in the coelom.
5. Some of the anterior body segments concentrate to form head.
6. Body is covered by a non-chitinous cuticle which may have chitinous **setae** formed by the epidermis. The **setae** or **parapodia** help in locomotion.
7. A majority of annelids are **hermaphrodites.** In some, sexes are separate.
8. Reproduction is generally sexual, but some may reproduce asexually by **regeneration**, i.e., by regrowing broken segments.

Example: ***Earthworm, Nereis (sandworm), sea mouse, cattle leech***



Annelida

A leech adhering tenaciously to human flesh.

At a single meal, a leech can take ten times its weight in blood, securing food for upto 9 months. They inject an anticoagulant to keep the blood flowing.

Characteristics of Phylum Arthropoda

This phylum accounts for nearly 80% of the animal kingdom. They inhabitate soil, fresh and marine water and are also found as parasites on other plants and animals.

1. The body is bilaterally symmetrical, **segmented** and divided into two regions: **cephalothorax** (head and thorax fused) and abdomen, or three regions: head, thorax and abdomen.
2. Head bears the sense organs and brain.
3. The soft body is protected by a hard, **chitinous**, inelastic exoskeleton. To allow free movement of parts, the exoskeleton has a number of **joints** with thin flexible membrane. These may be variously modified for walking, swimming, feeding and feeling.
4. Body cavity is reduced and filled with blood called **haemocoel** which lacks the red pigment haemoglobin.
5. To enable growth, the exoskeleton is periodically shed by a process called **moulting** or **ecdysis**.
6. Respiration is by gill, trachea, booklung (in some spiders) etc.
7. Sexes are separate.

Housefly

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Arthropods are divided into **four** classes: Crustacea, Myriapoda, Insecta and Arachnida.

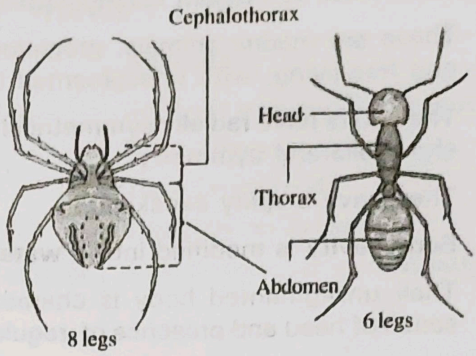
Examples

Crustacea: Crabs, crayfish, prawn, water-flea, lobsters, shrimps, cyclops (fresh water crustacean)

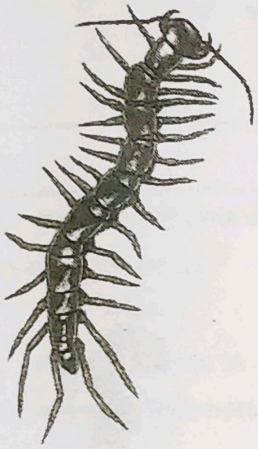
Myriapoda: Centipede, Millipede

Insecta: Housefly, mosquito, grasshopper, butterfly, beetle, Cockroach, locust, honeybee, ant, silver fish

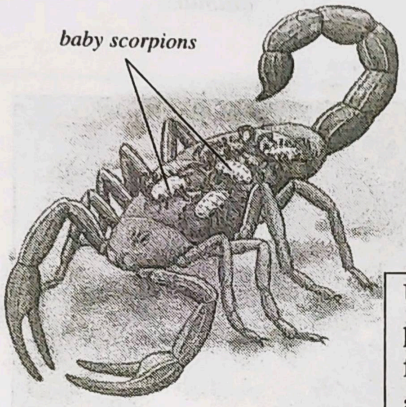
Arachnida: Ticks, mites, spider, scorpion



Spider (Arachnid) **Ant (Insect)**



Centipede



Scorpion

Grasshopper

Silverfish

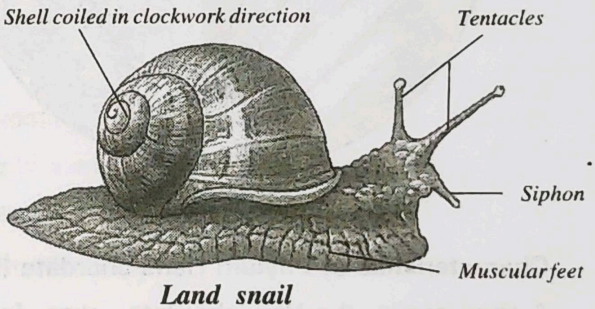
Unlike other invertebrates, scorpions do not lay eggs but produce their young ones live. The baby scorpions emerge from a special brood chamber in the mother's body and are carried around by their mother's until after their first moult.

Characteristics of Phylum Mollusc

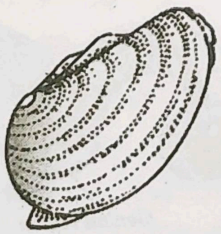
The molluscs have no close relatives and they constitute the teeming life forms of the fresh and marine waters.

1. Their soft bodies are divided into dorsal visceral mass and ventral foot and supported by a **calcareous** hard shell.
2. They breathe through gills called **ctendia.** Land molluscs have lungs.
3. Muscular foot helps in locomotion.
4. The sexes are usually separate.

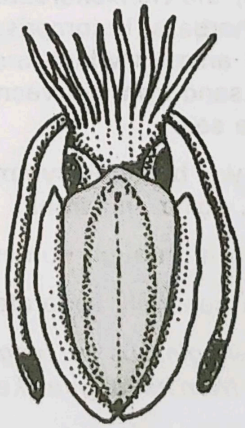
Example: ***Apple snail, slug, clams, oysters, fresh water mussel, squid, octopus (devil fish), sepia or cuttlefish***



Land snail



Mussel



Cuttlefish

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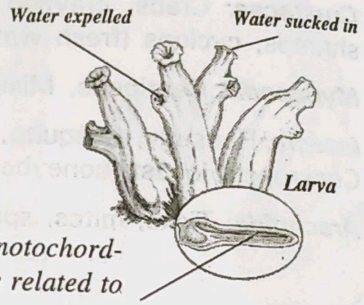
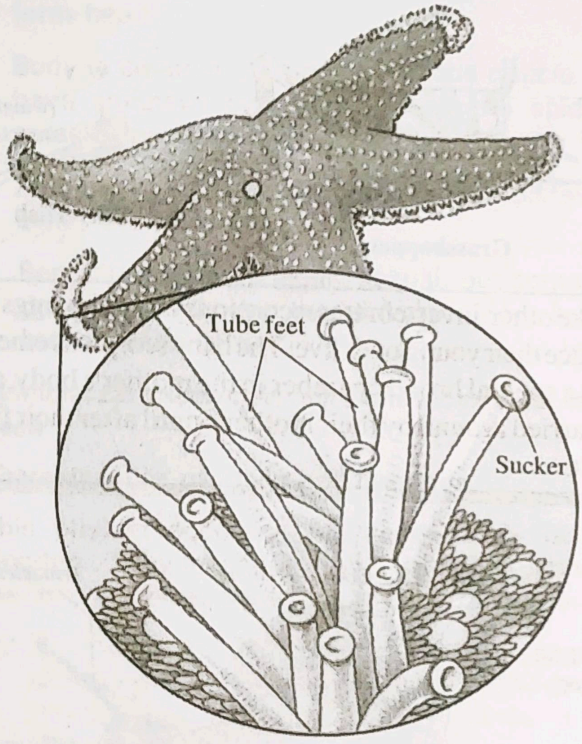
Characteristics of Phylum Echinodermata

1. These are marine animals, gregarious (live in groups) and free-living, with unsegmented bodies.
2. The adults have **radially** symmetrical bodies. The larvae show bilateral symmetry.
3. They have a **spiny** exoskeleton.
4. Body cavity is modified into a **water-vascular** system.
5. Their unsegmented body is characterised by the absence of head and presence of **regularly arranged arms.**
6. Locomotion is brought about by means of **tube feet.**

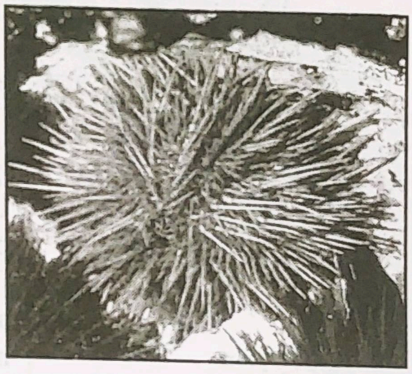
Example: ***Starfish, sea-urchin, sea cucumber, feather star.***



The larvae have a notochord- a structure that is related to the backbone of vertebrate animals.

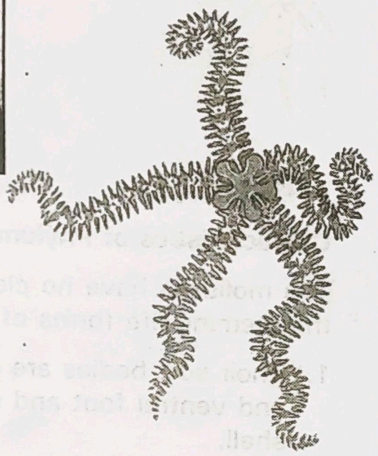


Star fish



Sea-urchin

Cushion fish



Brittlestar

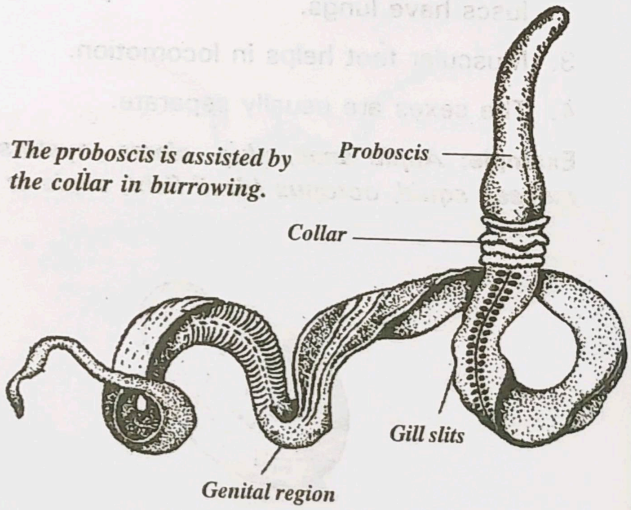
Characteristics of Phylum Hemi-chordata (half-chordates)

A third group, the **Hemichordata,** was formerly included in the Protochordata. It comprises worm-like, soft bodied, unsegmented animals which are exclusively marine, burrowing in the sand from between tide-marks to the abyssal regions of the sea.

1. Body shows **bilateral symmetry** and is divided into **proboscis, collar** and **trunk.**
2. Respiration is through numerous **gill-slits.**
3. Sexes are generally separate.

Example: *Balanoglossus or tongue worm (the animal derives its name from its tongue-like proboscis), Saccoglossus*

The proboscis is assisted by the collar in burrowing.



Hemichordata: ***Balanoglossus***

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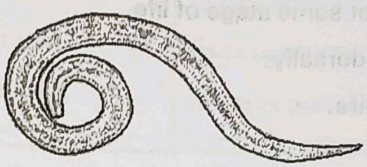
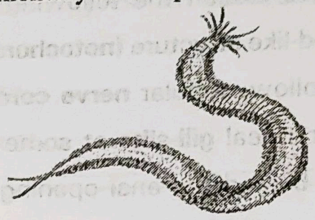
A Comparative Summary of the 'Worms'

Platyhelminthes	Nematodes	Annelida
1. Flat, ribbon-like, unsegmented bodies. 2. Bilaterally symmetrical. 3. Three-layered body. 4. Body cavity absent. 5. Alimentary canal has only one opening which serves as mouth and anus.	Soft, round, long, cylindrical bodies. Bilaterally symmetrical. Three-layered body. False body cavity present. Alimentary canal has separate opening for mouth and anus.	Soft body with ring-like segments. Bilaterally symmetrical. Three-layered body. True body cavity present. Alimentary canal opens at both ends.
 Liver fluke	 Hook worm	 Sand worm

Exercise 1

1. **Name the phylum to which the following belong:**
   (i) Amoeba (ii) Earthworm (iii) Centipede (iv) Octopus (v) Liverfluke
   (vi) Snail (vii) Hydra (viii) Round worm (ix) Tape worm (x) Brittlefish
2. **Name the phyla in which animals have:** (i) Bilateral symmetry (ii) Radial symmetry
3. **Name the locomotory organ of the following:**
   (i) Amoeba (ii) Paramoecium (iii) Trypanosoma (iv) Starfish
   (v) Mussel (vi) Earthworm (vii) Hydra (viii) Spider
4. **Identify the phylum with the help of clues given below:**
   (i) Body shows radial symmetry and locomotion is by means of tube feet.
   (ii) True body cavity, jointed appendages.
   (iii) Animal remains stationary, power of regeneration well developed.
   (iv) Life-cycle consists of a fixed (polyp) generation alternating with a swimming (medusa) generation.
   (v) Triploblastic, alimentary canal has only one opening which serves as mouth and anus.
   (vi) Hollow tubular body with a single large opening for the exit of water.
   (vii) This phylum has the largest number of species.
   (viii) Calcareous shell protects the body, while muscular feet help in locomotion.
   (ix) Cylindrical segmented body with true body cavity.
5. **State the functions of the following:**
   (i) Spicules in a bath sponge (ii) Nematocysts in jellyfish (iii) Nephridia in earthworm
6. **Give two points of differentiation between the following pairs:**
   (i) Nematoda and Annelida (ii) Porifera and Protozoa (iii) Arachnida and Insecta
7. **Explain the following terms:**
   (i) Hermaphrodite (ii) Cephalothorax (iii) Ectoparasite (iv) Endoparasite
   (v) Pseudopodia (vi) Regeneration (vii) Moulting (viii) Radial symmetry

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Phylum Chordate

Characteristics of Phylum Chordate

The chordate **notochord** (a flexible, rod-like structure) is the forerunner of the backbone and is the basis for the attachment of regularly attached muscles, the **myotomes.** Above the notochord lies a tubular hollow **nerve cord,** the anterior or "head" end of which is enlarged or folded to form a brain. Chordates exhibit the following basic characters.

1. A rod-like structure **(notochord)** present at some stage of life.
2. A hollow, tubular **nerve cord** situated dorsally.
3. Pharangeal **gill-slits** at some stage of life.
4. Tail behind the anal opening.

Of these, only the **nerve cord** persists throughout the life of the organism. The notochord may be replaced by a vertebral column and the gill slits disappear completely during the embryonic stage.

Chordates are divided into **Urochordate, Cephalochordata** and **Vertebrata.** Urochordata and Cephalo-chordata are very primitive forms and are regarded as **Protochordates.**

Characteristics of Sub-Phylum Vertebrata

1. Notochord replaced by a **vertebral column** which is made up of several vertebrae.
2. The brain is protected in a bony box called **cranium.**
3 Both, an endoskeleton and exoskeleton are present.
4. Heart is ventral (position).
5. Nerve cord is dorsal (position).
6. Red pigment **haemoglobin** is present in the blood.
7. Paired appendages do not exceed two pairs.
8. Respiration is by **gills** (aquatic animals) and **lungs** (land animals).
9. Sexes are separate.

Vertebrates are divided into Cyclostomata, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves, Mammalia.

Protochordata

The Protochordata are simpler forms of the chordate animals. This division includes a heterogeneous group of animals of the phylum chordata, most of which are fairly related to the vertebrates but none possess the full complement of vertebrate characters. For example, the notochord may be partially formed, or the vertebral column and skull may be lacking etc.

The Protochordates are divided into **two** groups:

1. **Tunicata** (or Urochordata or Ascidians): The adult forms are entirely different from the vertebrates.
2. **Cephalochordata:** Small, fish-like animal but has no fish-like skeleton, brain or eyes.

The "Fish" Vertebrates

The term **"fish"** coming from the Latin ***pisces***, can be loosely applied to three distinct classes of **"fish-like" vertebrates:**

1. ***Cyclostomata:*** The **jawless** fish.
2. ***Chondrichthyes:*** The **cartilaginous** fish. These have well developed jaws and teeth but the skeleton is wholly cartilaginous.
3. ***Osteichthyes:*** The **bony** fish. They range from the herring and cod to the tuna, sword fish, flying fishes, lung fishes, ray finned fishes, sea horses, puffer fishes and countless others that swarm the open seas and sea bottoms.

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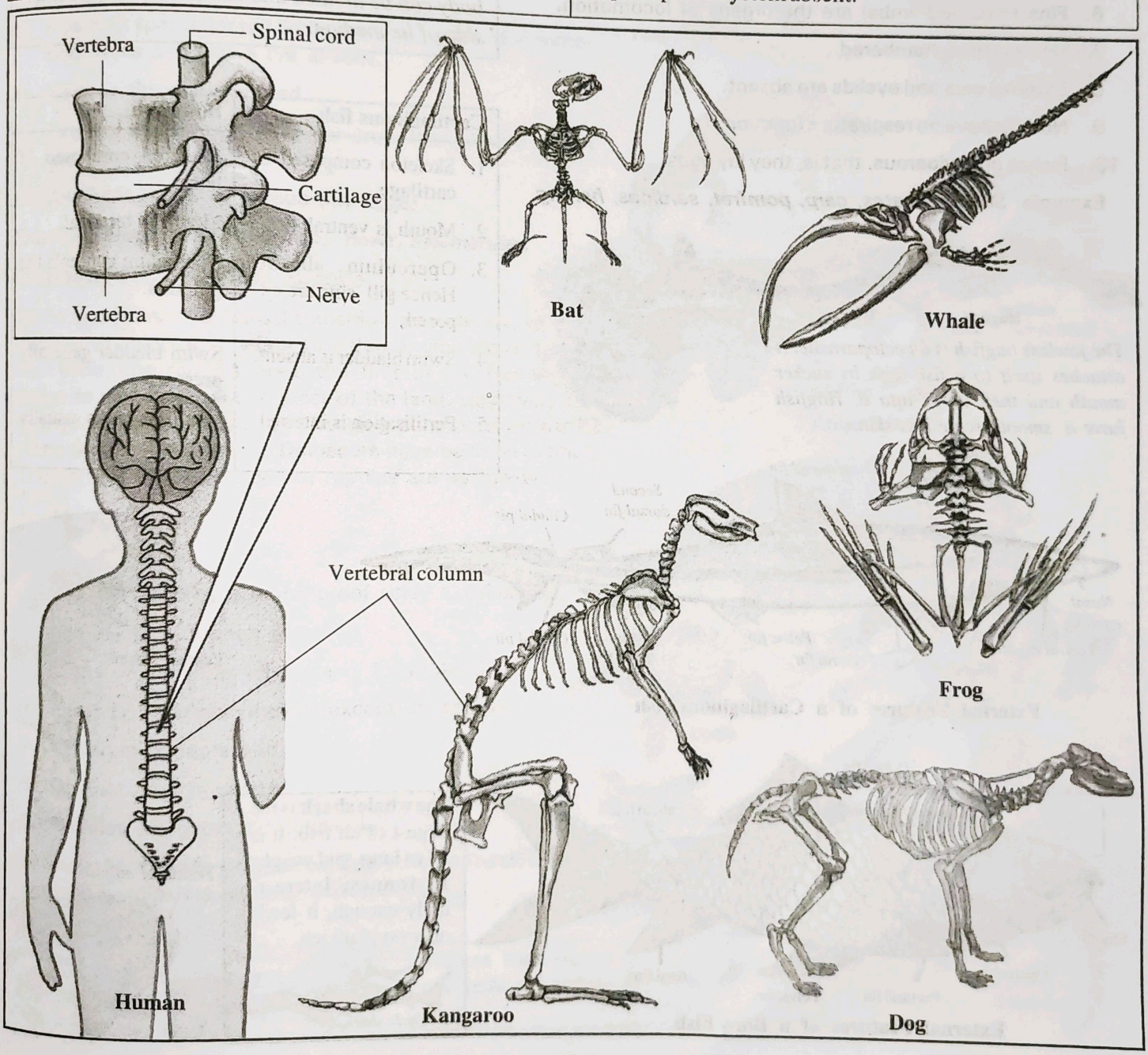
Major Differences between Vertebrates and Invertebrates

Vertebrates	Invertebrates
1. Notochord present at some stage of development.	Notochord is absent.
2. Heart is ventral and in a pericardial cavity.	Heart, if present, is dorsal.
3. Vascular system is always closed.	Vascular system may be open or closed.
4. Haemoglobin present in the red blood cells.	Haemoglobin generally absent. If present remains dissolved in the blood.
5. Sensory parts of eyes formed from the brain.	Eyes are formed by the skin.
6. Hepatic portal system present in higher forms.	Hepatic portal system absent.



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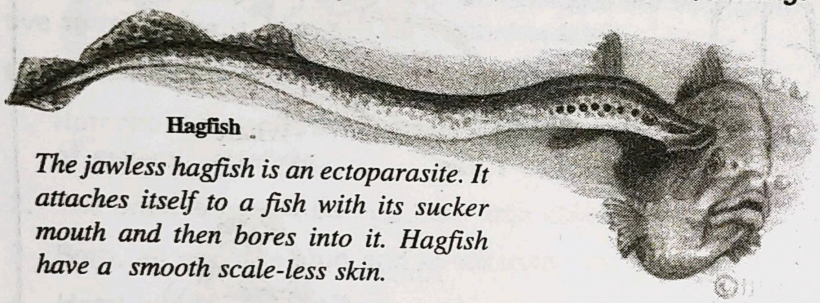
Characteristics of Class *Pisces*

The chief characteristics of the class are:

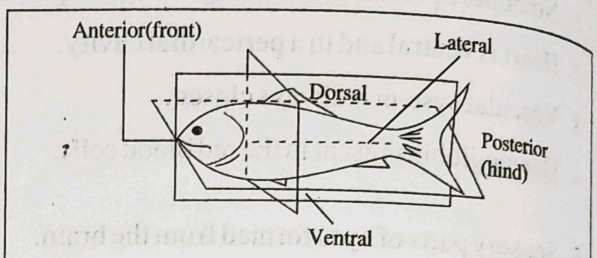
1. Aquatic habitat.
2. Streamlined body. The spindle-shaped body (neck absent) is an adaptation to its aquatic environment.
3. They are **cold blooded,** that is, their body temperature fluctuates with outside temperature.
4. Scaly exoskeleton. Body is covered by overlapping scales.
5. **Gills** are the organs of respiration.
6. **Fins** (modified limbs) are the organs of locomotion.
7. Heart is **two chambered.**
8. External ears and eyelids are absent.
9. Nostrils have no respiratory function.
10. Fishes are **oviparous,** that is, they lay eggs.

Example: ***Sharks, skates, carp, pomfret, sardines, herring.***



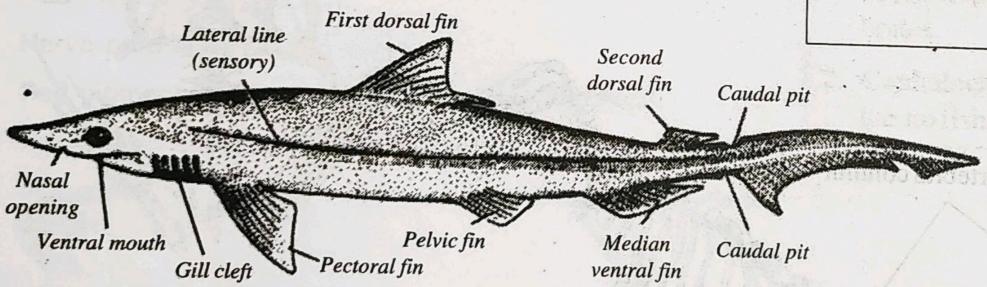
Hagfish

The jawless hagfish is an ectoparasite. It attaches itself to a fish with its sucker mouth and then bores into it. Hagfish have a smooth scale-less skin.

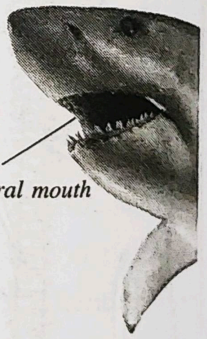


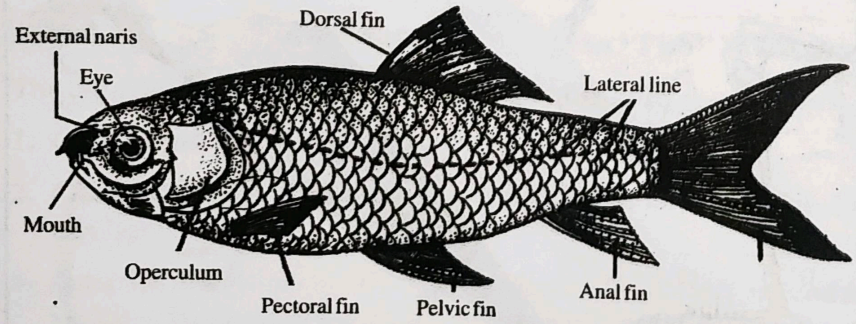
The body of the fish shows bilateral symmetery. Its body can be divided into similar halves on either side of its median.

Cartilaginous fish	Bony fish
1. Skeleton composed of cartilage.	Skeleton composed of bone.
2. Mouth is ventral.	Mouth is terminal.
3. Operculum absent. Hence gill slits are exposed.	Operculum conceals the gill slits.
4. Swim bladder is absent.	Swim bladder generally present.
5. Fertilisation is internal.	Fertilisation is usually external.



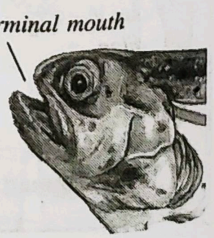
External Features of a Cartilaginous Fish





External Features of a Bony Fish

The **whale shark** is the largest of all fish. It is **18 m long,** and weighs **15 tonnes.** Interestingly enough, it feeds only on plankton.



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Characteristics of Class *Amphibia*

Evolution of the amphibians was the first stage in the conquest of the land. The amphibians lead a dual life. They can live on land, but begin their life in the water. Their chief characteristics are:

1. Aquatic and terrestrial habitat. Larva stage is aquatic. Adult can live on land and in water.
2. Cold-blooded.
3. Smooth, slimy, non-scaly exoskeleton, adapted to play a respiratory role.
4. Lungs are the main organs of respiration in the adult. Larvae breathe through gills.
5. Five digit (pentadactyl) limbs are the organs of locomotion. Nails and claws are absent.
6. Heart is **three-chambered.**
7. External ear is absent. The ear-drum (tympanum) lies on the skin surface.
8. Amphibians are **oviparous** (lay eggs).

Example: ***Frog, toad, tree-frog, newt, salamander.***

Characteristics of Class *Reptilia*

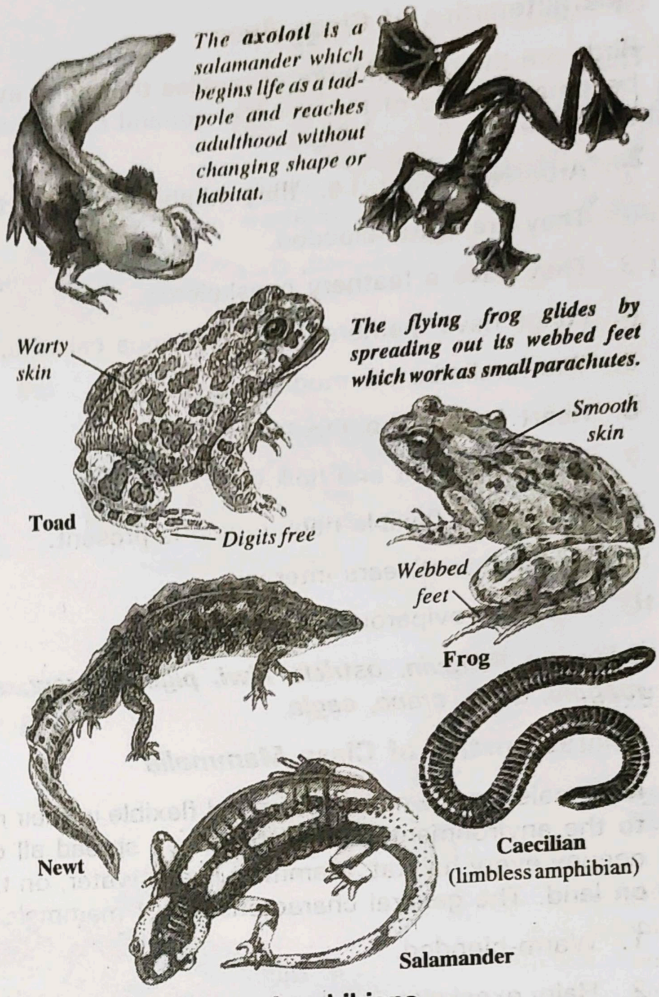
While amphibians remained transition animals due to their inability to completely adapt to either an aquatic or terrestrial habit, the reptiles were the first of the four-legged fishes to make a total conquest of the land. However, due to their inability to adapt to changing conditions on earth, many reptiles, such as the **Dinosaurs** have become extinct. The general characteristics of reptiles are as follows:

1. Terrestrial habitat.
2. Cold blooded.
3. Body covered by a water-proof scaly exoskeleton.
4. They respire through lungs.
5 Digits of the limbs have claws for protection.
6. Heart is three-chambered (except crocodiles).
7. Ear drum is depressed.
8. Distinct neck is present.
9. Reptiles are generally oviparous.

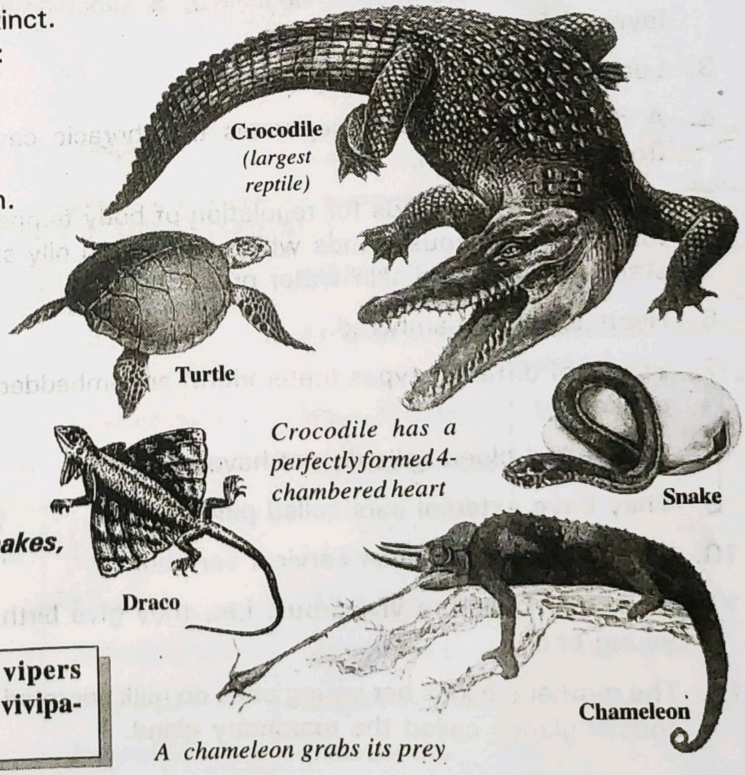
Example: ***Wall lizard , Chameleon, Draco (flying lizard), snakes, crocodiles, alligators, turtles, tortoise.***

Lizard

Snakes like vipers and boas are viviparous



Amphibians



A chameleon grabs its prey

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Characteristics of Class *Aves*

Birds are the descendents of reptiles that soon evolved to become masters of the air. The general characteristics of birds are:

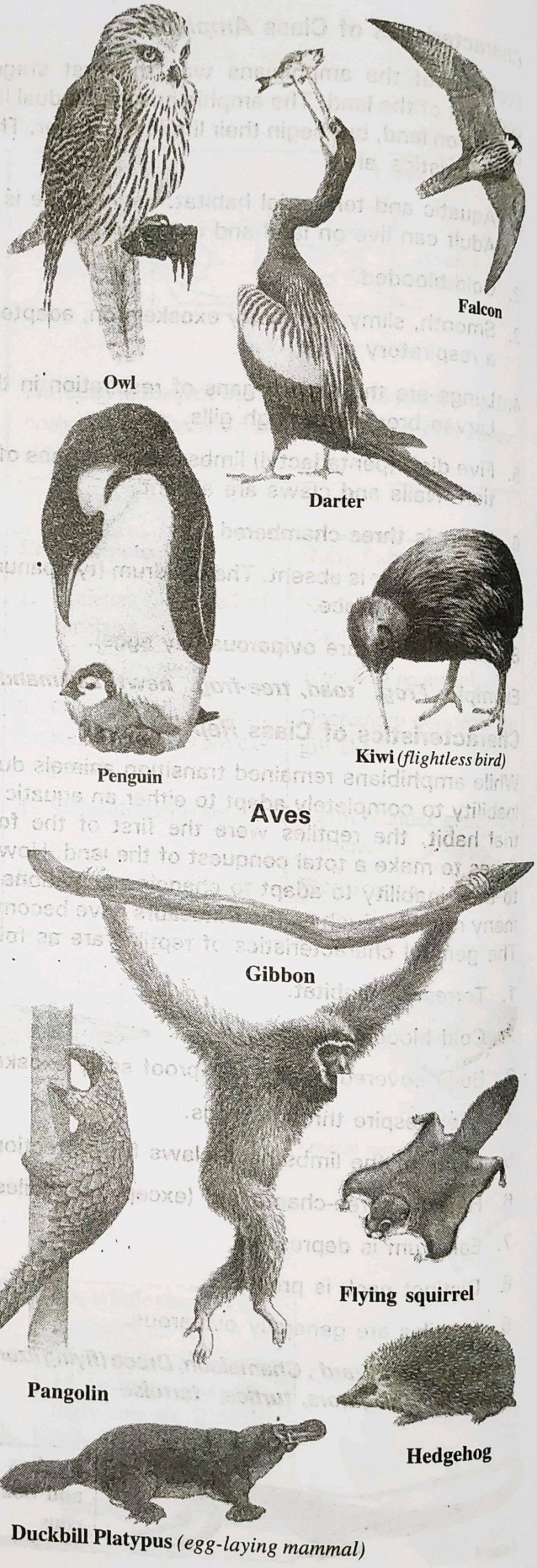
1. Arboreal habitat; i.e., they inhabit or live on trees.
2. They are warm-blooded.
3. They have a feathery exoskeleton.
4. Lungs have membranous extensions called air sacs.
5. The forelimbs are modified into wings.
6. Heart is four-chambered.
7. Bones are light and hollow.
8. A distinct, flexible neck region is present.
9. Teeth absent, ears internal.
10. Birds are oviparous.

Example: ***Penguin, ostrich, kiwi, pigeon, crow, swallow, magpie, duck, crane, eagle***

Characteristics of Class *Mammalia*

Mammals are the most active and flexible in their response to the environment. Hence they have spread all over and occupy every habitat. Mammals live in water, on trees and on land. The general characteristics of mammals are:

1. Warm-blooded.
2. Hairy exoskeleton acts as an insulating layer. In aquatic mammals, where hair is negligible, a subcutaneous layer of fat provides insulation.
3. Lungs are the organs of respiration.
4. A muscular diaphragm separates the thoracic cavity from the abdomen.
5. Skin has **sweat glands** for regulation of body temperature and **sebaceous glands** which secrete an oily substance to keep the skin water proof.
6. Heart is four–chambered.
7. Teeth of different types (heterodont) are embedded in sockets.
8. Mature red blood cells do not have a nucleus.
9. They have external ears called **pinna**.
10. Neck consists of seven cervical vertebra.
11. Most mammals are **viviparous,** i.e., they give birth to young ones.
12. The mother suckles her young ones on milk secreted by special glands called the **mammary gland**.



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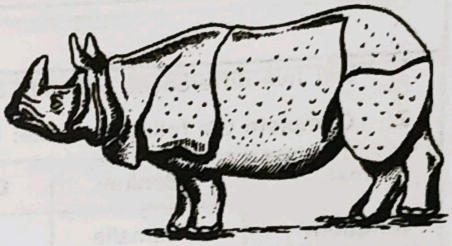
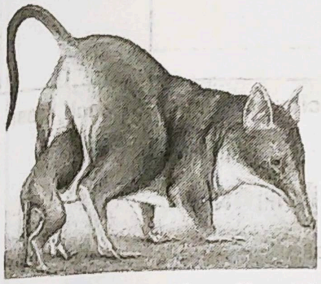
In marsupials the young are born in an immature state and develop in a pouch on the mother's abdomen.

Walrus



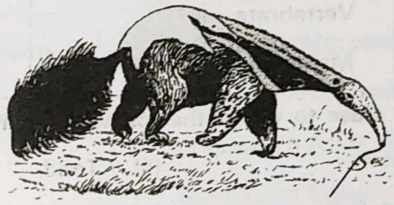
Rhinoceros

Bat

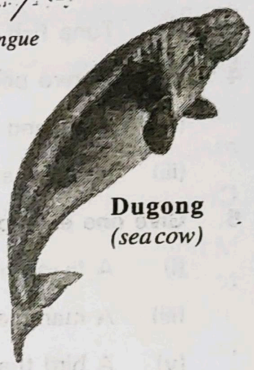


The Long-nosed bandicoot *has a pouch that faces backwards so that it does not fill up with earth during the animals burrowing activities.*

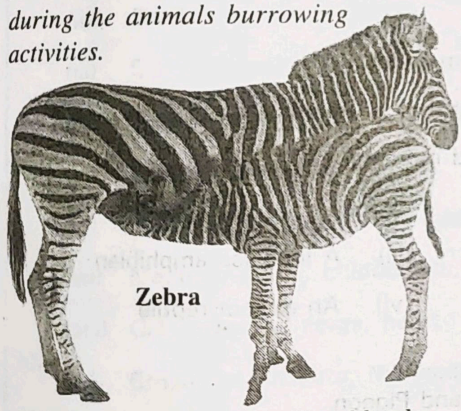
Marsupial mouse: *It has no pouch, so the young cling to the mother's fur*



Ant eater

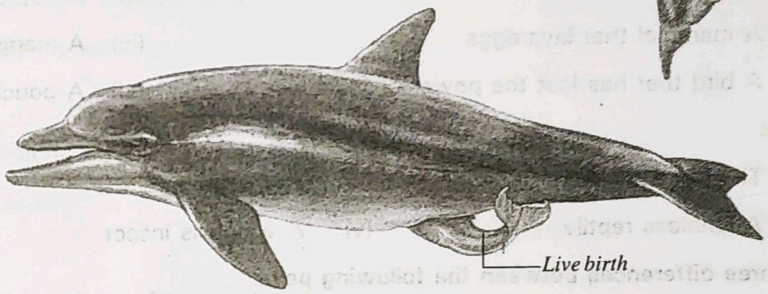


Dugong
(sea cow)



Zebra

Milk for the young is produced by the mother's mammary glands



Dolphin

A Comparative Summary of the Vertebrates

Characteristic	Pisces	Amphibians	Reptilia	Aves	Mammals
1. Habitat	Aquatic	Terrestrial and aquatic	Terrestrial	Arboreal	Terrestrial, aquatic and arboreal
2. Body temperature	Cold- blooded	Cold-blooded	Cold-blooded	Warm-blooded	Warm-blooded
3. Exoskeleton	Slimy scales	Smooth, slimy and non-scaly	Dry and scaly	Feathers present	Hairs present
4. Respiratory organ	Gills	Gills, lungs and skin	Lungs	Lungs	Lungs
5. Locomotory organ	Fins	Limbs	Limbs	Wings	Limbs
6. Heart	2-chambered	3-chambered	3-chambered	4-chambered	4-chambered
7. Propagation	Oviparous	Oviparous	Oviparous	Oviparous	Viviparous
8. Development	External	External	External	External	Intra-uterine

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Exercise 2

1. List five differences between chordates and non-chordates.

2. **Complete the following table: (The first one is done for you.)**

Animal	Monkey	Crocodile	Frog	Shark	Carp	Crow	Hagfish
Kingdom	Animalia						
Sub-Kingdom	Metazoa						
Phylum	Chordate						
Sub-phylum	Vertebrata						
Class	Mammalia						

3. **Name the class to which the following animals belong and mention two distinguishing characteristics of each class.**

(i) Rabbit (ii) Toad (iii) Sting ray (iv) Lamprey

(v) Tuna fish (vi) Kiwi (vii) Ant-eater (viii) Newt

4. **Mention two points of similarity and two points of difference between the following pairs:**

(i) Aves and Mammals (ii) Pisces and Amphibians

(iii) Reptiles and Amphibians (iv) Pisces and Aves

5. **Give one example of:**

(i) A flying mammal (ii) A hoofed mammal

(iii) A mammal that lays eggs (iv) A mammal that is aquatic

(v) A bird that has lost the power of flight (vi) A pouched mammal

6. **Name:**

(i) The largest fish (ii) The largest animal (iii) A limbless amphibian

(iv) A limbless reptile (v) A wingless insect (vi) An extinct reptile

7. **List three differences between the following pairs:**

(i) Bony fish and Cartilaginous fish (ii) Bat and Pigeon

8. **Which of the following characteristics is correct regarding:**

(i) Whale : Oviparous, milk glands, gills

(ii) Bat : Feathers, cold-blooded, projecting external ears

(iii) Fish : Scales, paired fins, vocal sacs

(iv) Snake : Limbless, slimy scales, warm blooded

(v) Whale shark : Scales, lungs, mammary glands

9. **State whether the given statement is true or false:**

(i) Mammals have a diaphragm separating the thorax and abdomen.

(ii) Birds have hollow bones.

(iii) Birds have external ears called pinna.

(iv) Reptiles do not have ears

(v) The lateral line is a sense organ in fish.

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Exercise 3 (Miscellaneous)

1. Fill in the blanks by selecting the correct alternative:

(i) Animals belonging to phylum _____ are exclusively marine. (Mollusc/Echinodermata/Arthropod)

(ii) Liver fluke is _____ while leach is _____. (Endoparasite/Ectoparasite)

(iii) Protozoa is _____ while porifera is _____. (Unicellular/Multicellular/Diploblastic)

(iv) Amoeba shows _____ symmetry. (Bilateral/Radial/No)

(v) The largest phylum among the non-chordates is _____. (Protozoa/Arthropoda/Mollusc)

(vi) _____ deals with the classification of living organisms. (Anatomy/Morphology/Taxonomy)

(vii) According to the five kingdom classification, amoeba is a _____. (Moneran/Protozoan/Protista)

(viii) _____ is a parasite in the liver of sheep, cattle. (Tapeworm/Liver fluke/Roundworm)

(ix) _____ is potato parasite. (Hairworm/Eelworm/Sandworm)

(x) _____ heep the annelids in locomotion. (Pseudopodia/Parapodia/Tentacles)

2. Pick the odd one out:

(i) Amoeba, sponge, hydra, frog.

(ii) Snail, slug, squid, snake.

(iii) Silverfish, cuttlefish, jellyfish, starfish, dogfish, crayfish.

(iv) Roundworm, hookworm, tapeworm, eelworm.

(v) Spider, scorpion, tick, ant.

(vi) Paramoecium, Amoeba, Plasmodium, Hydra

(vii) Medusa, polyp, cnidoblasts, spicules

(viii) Gills, trachea, lungs, heart

(ix) Crustacea, Insecta, Myriapoda, Arachnida, Echinodermata

(x) Sea-cucumber, sea-mouse, sea-urchin, starfish

3. State whether the given statement is true or false:

(i) Arthropods are divided into five classes.

(ii) The housefly has one pair of wings.

(iii) Silverfish is an insect.

(iv) Scorpions give birth to live young ones.

(v) Bivalve is a mollusc.

(vi) Molluscs respire through gills known as ctendia.

(vii) The phylum chordate is divided into nine classes.

(viii) All reptiles have a three chambered heart and are oviparous.

(ix) The whale shark is the largest fish and the blue whale is the largest of all animals.

(x) Elephant is the largest land animal.

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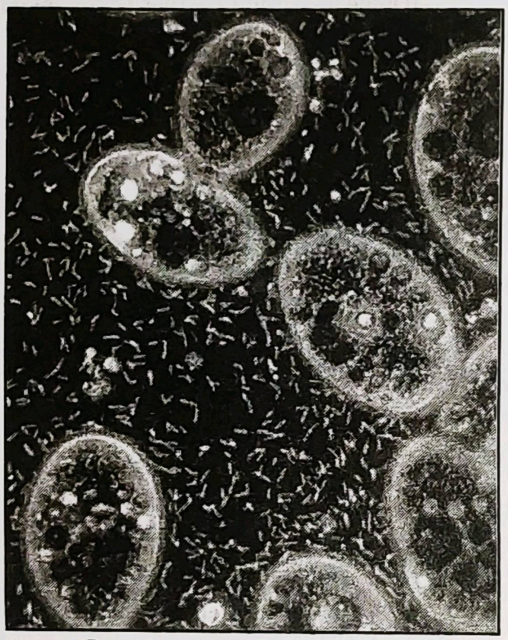
10
Economic Importance of Bacteria and Fungi

Introduction



Bacteria seen under a microscope

Bacteria and fungi play a very significant role in our lives. The transformation of milk into yogurt (curd), the digestion of food in our intestines, the fermentation of dough for preparing bread, *idli*, *dosa*, etc., the manufacture of alcohol and many many more applications are possible because of this group of organism.

Among the most important contributions of bacteria is perhaps the role they play in maintaining the nitrogen cycle in nature and also the many life saving drugs that are produced from the different bacteria.

While bacteria and fungi offer many benefits, they also cause a large number of diseases and cause spoilage of food.

However, the most harmful aspect is the dangerous tool they have become in the hands of irrational humans who use it as a means of spreading terror in the form of biological weapons. Biological warfare is the deliberate use of disease-causing biological agents such as bacteria, viruses, fungi, or biological toxins, to kill or incapacitate humans, animals or plants as an act of war.

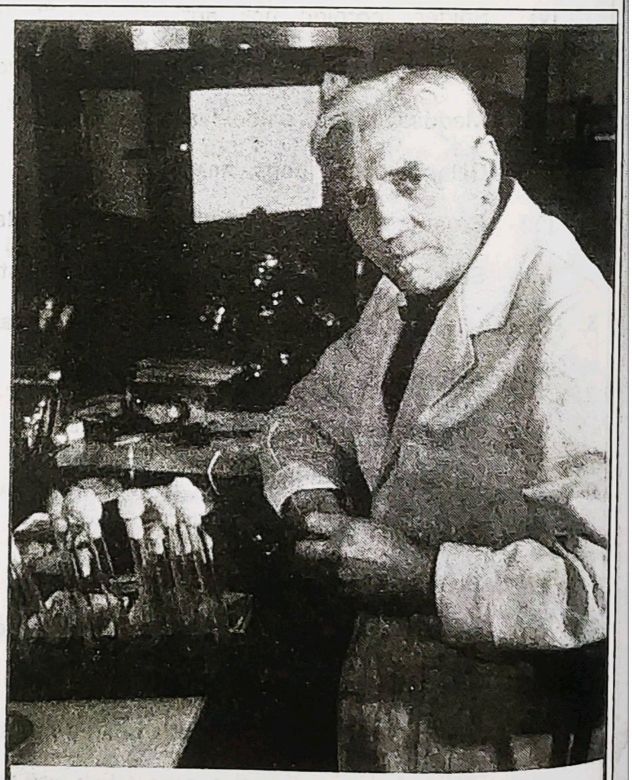
Antibiotics (*anti*, against; *bios*, life) are certain chemical substances secreted by a good number of soil bacteria and soil fungi, which have been found to check the growth of particular types of infective bacteria (germs) and even destroy them.

Antibiotics act like magic bullets shooting down the germs, which have invaded the human body and caused infectious diseases such as pneumonia, typhoid, diphtheria, tuberculosis, cholera, boils, abscesses, erysipelas, etc.

The first, best-known and most widely used antibiotic is ***penicillin*** isolated by the late **Sir Alexander Fleming,** an English bacteriologist, in 1929 from a blue-green mould of the soil, called *Penicillium notatum.* It is amazingly effective in diseases like scarlet fever, tonsillitis, sore throat, rheumatic fever, erysipelas, wound infections, abscesses, carbuncles, tetanus, pneumonia, meningitis, etc. Penicillin has come into general use since 1943-44 when mass production first got under way.

Another antibiotic, called **streptomycin,** was isolated in 1944 from a species of soil-bacteria, called *Streptomyces grisesus.* It is very valuable against tuberculosis.

Many bacteria and fungi are harmful to humans and cause diseases. For example, tuberculosis is caused by a bacteria.



Sir Alexander Fleming in the laboratory where research into antibiotics began with his accidental discovery of penicillin in 1928.

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Role of Bacteria

Beneficial Effects of Bacteria

A large number of bacteria are useful to humans in various ways, particularly in agriculture and in some of the industries.

1. Agricultural

(i) **Nature's scavengers:** Soil bacteria act upon the dead bodies of plants and animals and reduce the complex organic compounds to simple forms such as nitrates, sulphates and phosphates. Thus, these important inorganic compounds which would have remained locked within the dead bodies are returned to the soil for reabsorption by new plants.

Free nitrogen, carbon dioxide and water vapour formed during this process of bacterial decay is released unused back into the atmosphere.

(ii) **Nitrogen fixation:** Certain plants, especially of the legume family, have a special type of soil bacteria living in small rounded outgrowths on their roots called **nodules.** These bacteria are able to directly fix atmospheric nitrogen, convert them into nitrites, nitrates and make them available to the plant. On death of the plant, the nitrogen is again returned to the soil and atmosphere by the action of denitrifying bacteria. There are two types of nitrogen-fixing bacteria:

a. **Symbiotic Bacteria:** Bacteria belonging to the genus ***Rhizobium***, infect root hairs and gain entry into the cortex. The cortical cells divide to form a nodule within which the bacteria grows. The plant provides the bacteria with shelter and carbon compounds, while the bacteria in return, supplies the plant with nitrogenous compounds.

b. **Free-living Bacteria:** These bacteria live in the soil and possess the ability to fix free nitrogen of the air and convert them into ammonia, amino-acids and proteins. **Example:** ***Azobacter*** (Aerobic bacteria.)

Clostridium (Anaerobic bacteria.)

Role of Soil Bacteria

Ammonification: Anaerobic bacteria convert dead animal proteins into ammonia.

Nitrification: Aerobic bacteria oxidise ammonia first into nitrites and then into nitrates.

Nitrogen fixation: Convert free atmospheric nitrogen into ammonia, amino-acid, proteins.

Denitrification: Anaerobic bacteria breaks up ammonia into free nitrogen, which is returned to the atmosphere, for example, *bacterium denitrificans.*

Gobar Gas

The ability of certain bacteria to break down complex organic matter into simpler substances is utilised in Gobar Gas plants. Cow-dung, as well as other excreta are collected and subjected to bacterial action. The bacterial degradation of cellulose releases inflammable gases consisting mainly of methane.

The gas is used for domestic cooking. The solid and liquid residue is used as rich manure for agriculture. Thus, two purposes are served

1. Generation of domestic fuel.
2. Supply of rich manure.

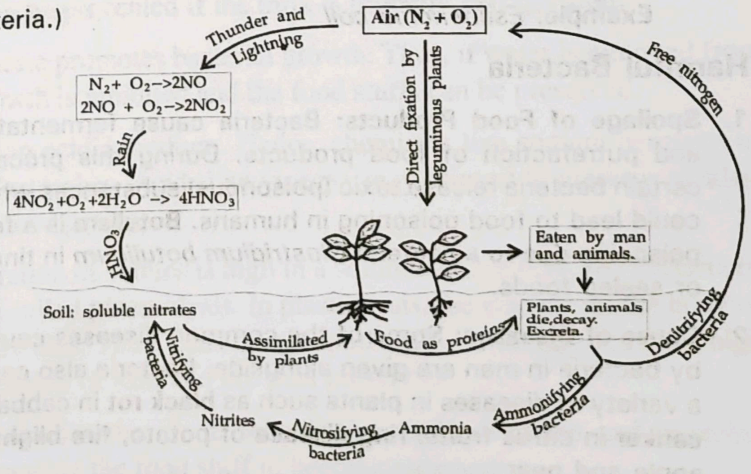
Nitrification

The process of converting complex animal protein into ammonia and other simpler nitrogenous compounds like nitrites and nitrates are known as **nitrification.**

The significance of this process arises from the fact that most plants are unable to directly utilize atmospheric nitrogen for their metabolic processes.

Nitrogen Cycle

The process of conversion of atmospheric nitrogen into essential nitrogenous compounds, and the decomposition of these compounds back to gaseous nitrogen constitutes the nitrogen cycle.



The Nitrogen Cycle in Nature

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2. Industrial Uses of Bacteria

The ability of bacteria to break down organic compounds into simpler bye-products with the help of their enzymes, finds several commercial applications.

(i) **Retting of Fibres:** Fibres from jute, flax and hemp are obtained by submerging the stems in water for variable periods. The middle lamellae of the fibres are acted upon by the bacteria growing in water, and the fibres are set free from the stem.

(ii) **Curing of Cheese, Tobacco and Tea:** The flavour of cheese, tea and tobacco depends upon the type and degree of fermentation and putrefaction that it has undergone. This process is known as curing and is brought about by different species of bacteria.

(iii) **Production of Vinegar:** Ethyl alcohol is converted into acetic acid (vinegar) by the action of aerobic bacteria, for example, *Acetobacter aceti.*

(iv) **Formation of Curd:** Curd is formed when lactose (milk sugar) of the milk is converted into lactic acid by the action of bacteria like *bacterium lactis acidi.* It is the lactic acid that imparts a sour taste to the curd.

3. Medicinal Uses of Bacteria

We are normally protected against virulent germs by certain bacteria which permanently reside in different parts of our body such as the mouth, respiratory tract, intestines. These wage chemical warfare against invading germs.

(i) **Antibiotics:** Life saving antibiotic drugs like chloromycetin, streptomycin, etc., are derived from bacteria. These help to control and cure diseases like pneumonia, typhoid, diphtheria, tuberculosis and wound infections.

Example: *Streptomyces griseus*

(ii) **Synthesis of Vitamin B:** A host of certain bacteria dwell in the intestines of humans and other vertebrates. These synthesize vitamins, especially of the B group.

Example: *Escherichia coli*

Harmful Bacteria

1. **Spoilage of Food Products:** Bacteria cause fermentation and putrefaction of food products. During this process, certain bacteria release toxic (poisonous) substances which could lead to food poisoning in humans. **Botulism** is a food poisoning due to a bacteria *Clostridium botulinum* in tinned or sealed foods.

2. **Cause of Diseases:** Some of the common diseases caused by bacteria in man are given alongside. Bacteria also cause a variety of diseases in plants such as **black rot** in cabbage, **canker** in citrus fruits, **ring disease** of potato, **fire blight** of apple and pear.

Bacterial processes that convert complex substances into simpler substances

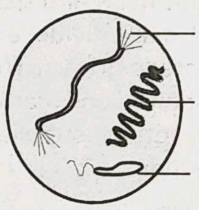
Decay: Complete breakdown of organic matter in the presence of air, without giving off foul smell.

Putrefaction: Bacterial decomposition of organic matter in limited air. This results in incomplete breakdown of the organic matter, and foul smell is emitted.

Fermentation: Breakdown of carbohydrates by the action of anaerobic bacteria.

Example of Bacterial Diseases in Humans

Typhoid	:	*Bacillus typhosus*
Tetanus	:	*Clostridium tetani*
Tuberculosis	:	*Myobacterium tuberculosis.*
Pneumonia	:	*Diplococcus pneumoniae*
Dysentery	:	*Bacillus dysenteriae*
Cholera	:	*Vibrio cholerae*
Diphtheria	:	*Corynebacterium diphtheriae*

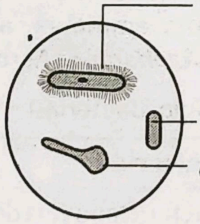


Spirillum minus (rat bite fever)

Treponema (Syphilis)

Vibrio cholerae (Cholera)

Spirilli

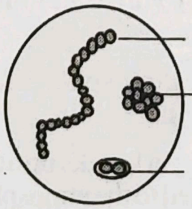


Bacillus typhosus (typhoid fever)

Bacillus tuberculosis (tuberculosis)

Clostridium tetani (lockjaw) or Tetanus

Bacilli



Streptococcus (scarlet fever)

Staphylococcus (blood poisoning, boils)

Diplocooccus (pneumonia, meningitis)

Cocci

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3. **Biological weapons**

Biological weapons (''bio-weapons'') are living organisms that reproduce within their host victims. Biological weapons are toxic materials produced from microbes or artificially manufactured toxic substances that are used to intentionally interfere with the biological processes of a host.

Biological weapons may be used to target living organisms such as humans, animals or vegetation. They may also be used to contaminate nonliving substances such as air, water and soil.

There are a variety of microorganisms that can be used as biological weapons. Agents are commonly chosen because they are highly toxic, easily obtainable and inexpensive to produce, easily transferable from person to person, can be dispersed in aerosol form, or have no known vaccine.

Microbe	Natural Environment	Diseases/Symptoms
Anthrax Bacillus anthracis	Soil	Pulmonary Anthrax Septicemia, Flu-like symptoms
Clostridium botulinum	Soil	Inhalation
Clostridium perfringens	Intestines of humans and other animals, Soil	Gas gangrene, Severe Abdominal Cramps, Diarrhea
RICIN Protein Toxin	Extracted from Castor Bean Plants	Severe Abdominal Pain, Watery and Bloody Diarrhea, Vomiting, Weakness, Fever, Cough, and Pulmonary Edema
Smallpox	Eradicated from Nature, Now Obtained from Laboratory Stockpiles	Persistent Fever, Vomiting, Rash on Tongue and in Mouth, Rash and Bumps on Skin

Protection of Food

Food stuffs can be prevented from spoilage by the following methods:

1. **Use of Extreme Temperatures**

   (i) **Low Temperature**: Bacteria and fungi become inactive at freezing temperature of water. Hence, refrigeration of milk, fruits and vegetables or keeping frozen meat, fish, vegetables in cold storage prevents spoilage for long periods.

   (ii) **High Temperature** (sterilisation): The temperature of boiling water kills bacteria but not their spores. Boiling at increased pressure such as in pressure cookers, destroys the spores also. Used in food canning industry.

   (iii) **Pasteurisation**: This is a technique of partial sterilisation applied usually to milk. The process involves heating milk to about 60°C for 30 minutes followed by sudden and rapid chilling. A majority of the bacteria are destroyed though some may persist. **Souring of milk** can be prevented if the milk is properly **refrigerated.**

2. **Dehydration** (Removal of water): Presence of moisture promotes bacterial growth. Thus, if water is removed from grains, meat, fish, vegetables and milk, bacterial growth is inhibited and the food stuffs can be preserved.

3. **Use of Chemicals**: Most bacteria are destroyed in an acidic medium. Hence, chemicals like sodium benzoate or benzoic acid are added to preserve tinned foods and squashes. Acids like vinegar, may be used to preserve pickles, and boric acid may be added to prevent infection in food grains.

4. **Use of Concentrated Solutions**: When the concentration of solutes is high in a solution or medium, the bacteria or fungi entering the medium is destroyed by a process called **plasmolysis.** In plasmolysis, the water from the body of the organism is removed and it shrinks and eventually dies. Thus, jams do not spoil easily since they contain a high concentration of sugar. Pickles have a high concentration of salt, and are thus preserved.

5. **Use of Irradiation**: **Ultraviolet rays** effectively sterilise the air in schools, hospitals, factories and bakeries. Radioactive **radiation** sterilise food stuffs without causing the food stuff to become radioactive.

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Role of Fungi

Fungi contribute significantly to the economy by their role in the food industry, medicine, agriculture and the chemical industry.

1. Food Industry

a. **Mushrooms** are cultivated on a commercial scale for their nutritive value. Mushrooms are rich in proteins and vitamins.

b. **Food yeast** contains vitamins of the B group, E group and 15% proteins. It is a useful cure for many vitamin deficiency diseases.

2. Medicinal Use

a. **Antibiotics:** Antibiotics are substances synthesized by certain living organisms and have the capacity to inhibit (prevent) the metabolic activities of other organisms. Important antibiotics are produced by the moulds which check the effects of disease producing bacteria.

Some Antibiotics of Fungal Origin

1. **Penicillin**	:	Used to cure pneumonia, venereal diseases.
2. **Ephedrine**	:	Synthesised by yeast and used against asthma.
3. **Ergot**	:	Controls bleeding during child birth.
4. **Erythromycin**	:	Active against whooping cough and diphtheria.

b. **Synthesis of Fats and Proteins:** Fats are synthesized by aspergillus, penicillium, while yeasts are used to prepare proteins.

c. **Synthesis of Vitamins and Enzymes:** Many enzymes such as pectinase, amylase, glucose, oxidase and invertase are synthesized by fungi of the *Penicillium* and *Aspergillus* genus.

3. Role in Industry

a. **In Breweries:** Fermentation of sugar by yeast produces **ethyl alcohol** and carbon dioxide. In wine-making industries the alcohol formed is the main product. Carbon dioxide given off as bye-product is solidified and sold as **'dry ice'**.

b. **In Bakeries:** In bread-making industry, **yeast** is used as a source of carbon dioxide. As the carbon dioxide rises through the dough air spaces are formed, lending sponginess to the bread.

c. **Cheese Processing Industry:** *Penicillium* and *Aspergillus* are employed in flavouring cheese.

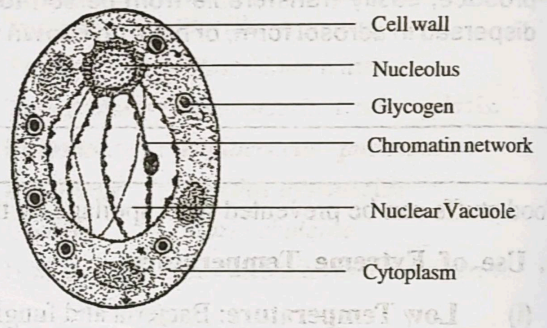
d. **Chemicals Industry:** Many acids like citric acid, gallic acid, gluconic acid are synthetically prepared from fungi, especially of the aspergillus genus.

Yeast

Yeast is a unicellular fungi occurring freely in the air. It grows readily in sugary solutions and causes their fermentation, releasing carbon-dioxide. Hence, its application in the brewery and bakery industry.

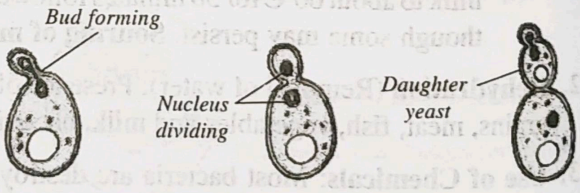
$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Zymase}} \underset{\text{Ethyl alcohol}}{2C_2H_5OH} + 2CO_2 + 2ATP$$

Yeast has a distinct cell wall, nucleus and nucleolus. Yeast respires anaerobically.

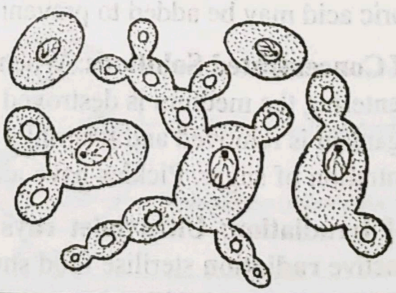


It reproduces asexually by a process called **budding**.

Sexual reproduction takes place by the process of **conjugation**.



Stages in Budding



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4. Role in Agriculture

* **Soil fertility:** Saprophytic fungi living on dead bodies of plants and animals, bring about their decay and decomposition by secreting enzymes. Thus, in a manner similar to bacteria, they help in enriching the soil and in the biochemical cycling of materials.
* Soil fungi also absorb inorganic salts and prevent them from being lost from the soil by leaching.
* Certain fungal inhabitants of the soil help to fight diseases caused in plants by other soil-borne fungi.

Harmful Activities of Fungi

1. **Diseases:** Fungi cause diseases in plants causing damage to crops, humans and cattle.
2. **Food spoilage:** Fruits, vegetables, meat, dairy products, bread, etc., are spoiled by certain fungi especially moulds, and those of the penicillium and aspergillus genus.
3. **Tropical deterioration:** The warm, moist conditions of the tropical regions especially during the monsoons provide a congenial environment for the growth of fungi. The fungi invade a variety of articles such as clothing, leather goods, photographic materials, electrical equipments, etc. This is known as **tropical deterioration.**

Important Fungal Diseases of Plants
1. Downy mildew of grapes.
2. Late blight of potatoes.
3. Rust in wheat and other grasses.
4. Smut in corn, wheat and other cereal crops.
5. Leaf spot in ground nut.
Fungal Diseases of Humans
1. Hay fever and allergies.
2. Thrush: A throat and mouth infection.
3. Ringworm: A skin disease characterised by circular patches (with raised margins), and severe itching.

Exercise

1. **Explain briefly the role of bacteria:**
   (i) As Nature's scavengers. (ii) In nitrogen fixation. (iii) In the manufacture of gobar gas.
2. Distinguish between decay and putrefaction.
3. **What is meant by:**
   (i) Retting of fibres (ii) Curing of cheese, tobacco (iii) Biological weapon?
4. **Name the bacterium associated with the following:**
   (i) Production of vinegar (ii) Formation of curd
5. Name two antibiotics derived from bacteria.
6. Name three diseases in humans caused by bacteria.
7. Name three diseases in plants caused by bacteria.
8. **Explain how the following methods help prevent food spoilage:**
   (i) Use of low temperatures (ii) Use of high temperatures (iii) Dehydration
   (iv) Use of concentrated solutions (v) Use of irradiation (vi) Use of chemicals
9. **Explain briefly:**
   (i) Fungi are heterotrophic.
   (ii) The living room in every house must receive direct sunlight daily even if for a short duration.
   (iii) Denitrification bacteria of the soil are a boon and a curse to the farmer.
   (iv) Yeast is used in bakeries and breweries.
10. **State/ Name three:**
    (i) Useful effects of bacteria. (ii) Harmful effects of bacteria.
    (iii) Harmful activities of fungi. (iv) Economic importance of yeast.

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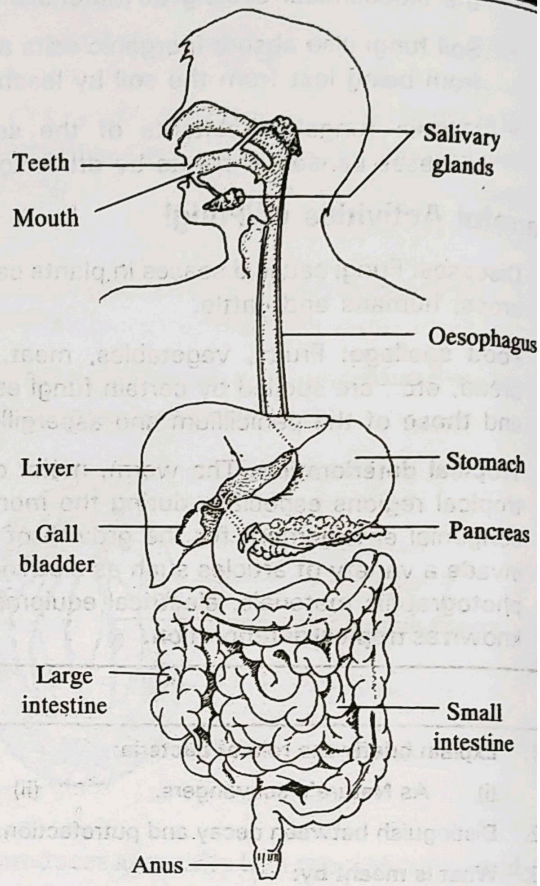
11
Nutrition and Digestion in Humans

Introduction

Nutrition is the process by which living beings obtain or synthesize food and convert them into simple compounds by a series of biochemical processes so that they can be absorbed and utilised by the body cells.



Need for Nutrition

Food is the fuel that keeps the body alive. Food is required:

(i) To provide energy for various metabolic processes in the body.

(ii) For the growth of new cells and the repair or replacement of worn out cells.

(iii) To develop resistance against diseases.

Since the very survival of an organism depends on food, different organisms, in accordance with their size, structure and physiology have adopted various physical, chemical and physiological modes or processes of handling food and converting it into simple chemical compounds that can be absorbed and utilised by the cells of the body for growth. This complex process of ingesting, digesting, absorbing and assimilating the food is termed as **nutrition**.

The various modes of nutrition exhibited by plants and animals can be understood from the following chart.

Modes of Nutrition

Autotrophic

Ability of the organism to prepare its own food.

Holophytic

This mode of nutrition is characteristic of plants whereby they prepare complex food substances using simple raw materials.

Example: During **photosynthesis**, green plants use carbon dioxide and water to synthesize carbohydrates.

Non-green plants like **nitrifying bacteria**, synthesize food by **chemosynthesis**, a process driven by the energy released by inorganic chemical reactions.

Heterotrophic

Organism is unable to prepare its own food. Hence, obtains prepared food.

Holozoic

This mode of nutrition is characteristic of animals whereby simple substances are obtained from solid, complex, food substances.

Example: Animals take in complex proteins or carbohydrates and break them into amino acids and simple sugars respectively.

Saprophytic

The organism absorbs nutrition from dead or decaying organic matter.

Example: Bread moulds (fungus)

Parasitic

The organism derives nutrition from a living host without helping it in any way.

Example: Tapeworm lives in the intestines of the host and absorbs nutrients from the host.

The **cuscuta plant** obtains prepared food from the stem of the host plant.

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Diet and Dentition

Kinds of Diet

According to the type of food they ingest, organisms may be classified as herbivorous, carnivorous, omnivorous or carrion-feeders.

1. **Herbivores:** These are plant-eating animals, for example, elephants, giraffes, horses and cattle.
2. **Carnivores:** Flesh-eating animals like dogs, cats, lions, tigers, wolves, crow, etc., are said to be carnivorous.
3. **Omnivores:** The omnivorous are both plant-eating and flesh-eating. Man is an example of an omnivorous animal.
4. **Carrion-feeders:** These are animals which feed on the dead bodies of other animals. For example, vulture and hyena.

Herbivores are animals that feed on plants

Types of Teeth

Most animals that feed on solid plant or animal food, are provided with a set of teeth that enables them to break the food into smaller particles and also chew it into a soft pulp so that the food can be easily swallowed.

Teeth of animals are of two types:

a. **Homodont teeth:** These consist of only one type of teeth.

b. **Heterodont teeth:** These consist of more than one type of teeth which are adapted for various functions.

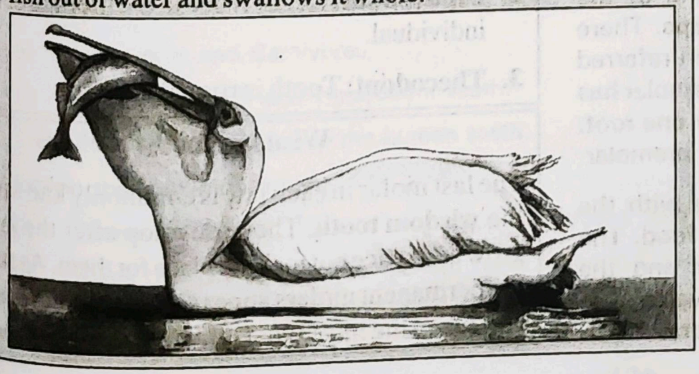
Even among the heterodont, the herbivores and carnivores have their teeth differentiated to meet their special requirements based on the nature of their diet.

Since plant fibres are generally tough and requires chewing, **herbivorous mammals** have flat, high-crowned molars that wear down slowly.

Carnivorous mammals on the other hand have long pointed canines to seize and stab their prey. Their powerful jaws can even crush large bones. Most of them swallow their food without proper chewing.

Homodont Teeth	Heterodont Teeth
1. Only one type of teeth present. These are almost alike in shape size and function.	More than one type of teeth present, differing in shape, size and function.
2. Teeth are used only for catching prey as homodont do not chew their food. They swallow their prey.	Teeth are used for varied functions such as biting, tearing, crushing and chewing food.
3. *Example:* Reptiles, fish	*Example:* Mammals
Snake	**Bison**

Many carnivores are not provided with teeth and do not chew their food at all. For example, the pelican uses its pouch to scoop the fish out of water and swallows it whole.



Did you know?

1. The tusks of elephant are actually the incisors that have become very long.
2. Beavers, rats and other rodents have continuously growing teeth.
3. Fish and reptiles lose and replace their teeth periodically.
4. Birds, toads, turtles and certain insects have no teeth.
5. Certain whales do not have teeth.

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Human Dentition

Human beings grow two sets of teeth - the **deciduous** teeth and the **permanent** teeth-both of which have the same basic structure, but occur at different times in the individuals' life.

a. **Deciduous Teeth:** Also known as the **milk teeth** or the **primary teeth**, the deciduous teeth develop when the foetus is $2\frac{1}{2}$ months old and begin to appear externally as oval buds when the child is about 6-8 months old. As each teeth grows, it pushes out of the gums. This is known as **teething.** The growth of the entire set of twenty deciduous teeth is generally completed by the time a child is two years old.

There are **twenty deciduous teeth**, ten in each jaw. They consist of three kinds of teeth, each jaw having **four incisors, two canines** and **four molars**. The deciduous teeth help the permanent teeth to erupt in their normal positions. Most permanent teeth develop close to the roots of the deciduous teeth.

Between the ages of three and twelve, the deciduous teeth start making way for the permanent teeth. Their roots begin to dissolve and by the time the permanent teeth are ready to erupt, the crown of the deciduous tooth becomes loose and falls out.

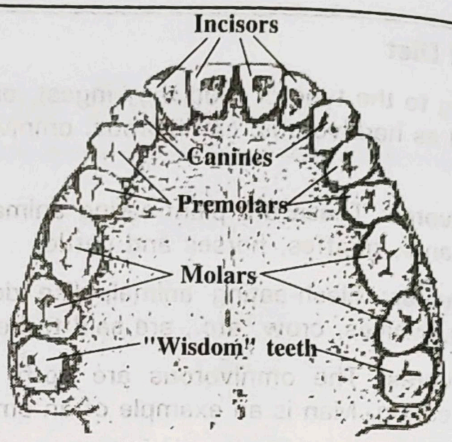
b. **Permanent teeth:** In all there are **thirty two** permanent teeth, sixteen in each jaw. These are larger than the deciduous teeth and consist of four types, each jaw having four incisors, two canines, four premolar and six molars.

1. **Incisors** (four in each jaw): Centrally positioned, these front teeth form the biting teeth used for cutting food. They are characterised by a sharp, straight, chiselled cutting edge and a single root canal. The **central incisors** of the lower jaw are the **smallest permanent teeth.**

2. **Canines** (two in each jaw): Flanking the incisors in each jaw, the canines are used along with the incisors for biting and cutting. The sharp, long and pointed teeth is particularly efficient in tearing fleshy or fibrous food. These also have one root.

3. **Premolar** (four in each jaw): The premolar have a broad, humped surface which enables easy mashing of the food. The small surface humps are called **cusps**. There being generally two cusps, premolar are often referred to as **bicuspids**. Usually only the **first upper premolar has two roots while the other premolar have only one root.** The premolar erupt in place of the deciduous premolar.

4. **Molars** (six in each jaw): The molars, along with the premolar are used for crushing and grinding food. The molars are much larger than the premolar and the various molars normally have three to five cusps. Accordingly they may have two or three roots.



Arrangement of Teeth in the Upper Jaw of an Adult Man

Kinds of Teeth present in Humans

Dental Formula

The number of permanent teeth of mammals is represented by the formula

$$\left.\begin{matrix}\text{I: C: Pm: M} \\ \text{I: C: Pm: M}\end{matrix}\right\}$$ I = incisors; C = canines; Pm = premolars; M = molars

The formula indicates the number of teeth in one-half of each upper jaw.

Example: Adult human: $\frac{2\ 1\ 2\ 3}{2\ 1\ 2\ 3}$ (32)

Human child : $\frac{2\ 1\ 2\ 0}{2\ 1\ 2\ 0}$ (20)

Characteristics of Human Teeth

1. **Heterodont:** Consist of more than one type of teeth which are adapted for various functions.
2. **Diphyodont:** Occur twice in the lifetime of the individual.
3. **Thecodont:** Tooth is rooted in cavity.

Wisdom Tooth

The last molar in each jaw is commonly known as the **wisdom tooth.** These develop after the jaws grow and space out making place for them. As such the permanent molars appear in adulthood, generally when the individual is in his early twenties.

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Parts of a Tooth

The tooth consists of two main regions, the part above the gums called the **crown** and the part below the gums called the root. In section, the following parts are seen.

1. **Enamel:** Forming the outer covering of the crown, the enamel is the **hardest substance in the body.** Composed of non-living materials like mineral salts (mainly calcium) and small amounts of water, the enamel can withstand tremendous pressures while biting, cutting and crushing.

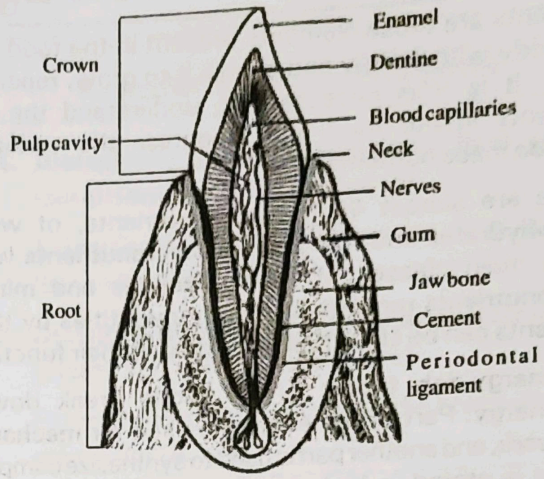
   Although white in colour, the enamel often appears yellowish since it is transparent and the yellow dentine below it often shows through. With age the enamel wears away and the dentine becomes exposed.

2. **Dentine:** Below the enamel, there is a hard bone-like tissue called the dentine. Also composed of minerals and water, this yellow coloured substance contains living cells as well. These cells can generate and add more cells to the inside of the tooth.

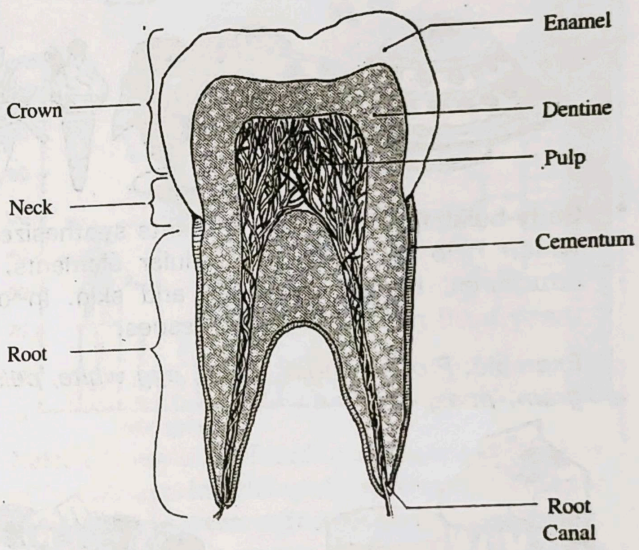
3. **Cement:** Overlying the dentine in the root region of the tooth is the cement. Almost as hard as bone, the cement in most cases meets the enamel at the junction where the root ends and the crown begins. Like the dentine and enamel, the cement is made up of mainly mineral salts and water.

4. **Periodontal ligament:** The periodontal ligament consists of very small fibres which extend through the cement and into the bony socket. It helps to anchor the tooth in the socket and also serves as a shock absorber during chewing.

5. **Pulp:** The pulp forms the innermost layer of the tooth. It can be divided into two distinct regions - the pulp chamber (in the crown) and the root canal (in the root). This layer is richly supplied with blood vessels and nerves. While the blood nourishes the tooth, the nerves receive and transmit sensations of pain to the brain. The blood vessels and nerves enter the root canal through a tiny hole at the tip of the root and extend into the pulp chamber.



Vertical Section of a Tooth with one Root Canal



Vertical Section through a Molar Tooth

Exercise 1

1. **State one difference between the following pairs:**
   (i) Herbivores and Carnivores
   (ii) Homodont teeth and Heterodont teeth.
2. State three characteristics of the human teeth.
3. **Explain the following terms:**
   (i) Permanent teeth (ii) Deciduous teeth (iii) Wisdom teeth
4. (i) Name the four types of permanent teeth found in humans.
   (ii) State their function. Also state how each is adapted to perform its function.

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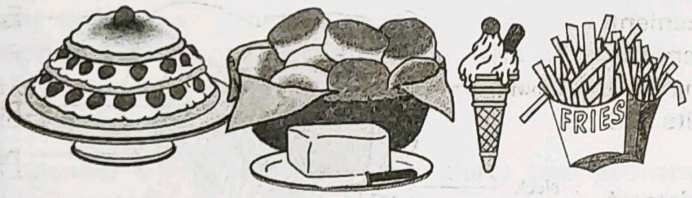
Nutrients are those elements present in the food which provide the body with energy and enable it to grow, repair and maintain itself. It is thus necessary to understand the exact role of nutrients in our food and recognise the various foods that provide these nutrients.

There are almost 40 essential nutrients, of which **proteins, carbohydrates** and **fats** are the **macronutrients** which form the three main classes of food. **Vitamins** and **minerals** are the **micronutrients** required in minute quantities by the body. Food nutrients can be classified according to their function:

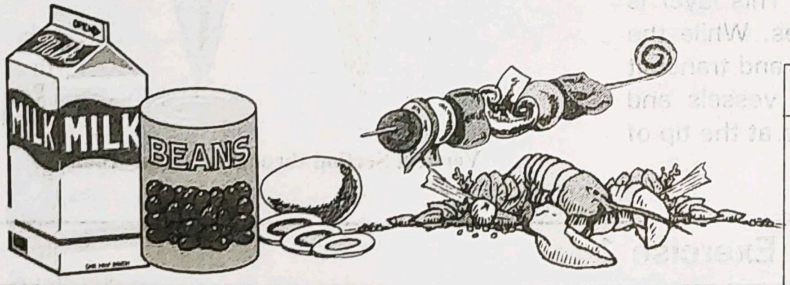
* **Energy-rich foods:** These foods break down to release energy. Part of the energy is used for **mechanical muscular work,** and another part is used to synthesize complex compounds or is stored in high energy compounds such as **adenosine triphosphate (ATP) or creatine phosphate (CP).**

  Example: *Fats and Carbohydrates (rice, wheat, potato, oil, ghee, sugar)*



* **Body-building foods:** The nutrients synthesize compounds which help to make the cellular elements, intracellular structures, bones, cartilages and skin. In other words, these build mass and repair tissues.

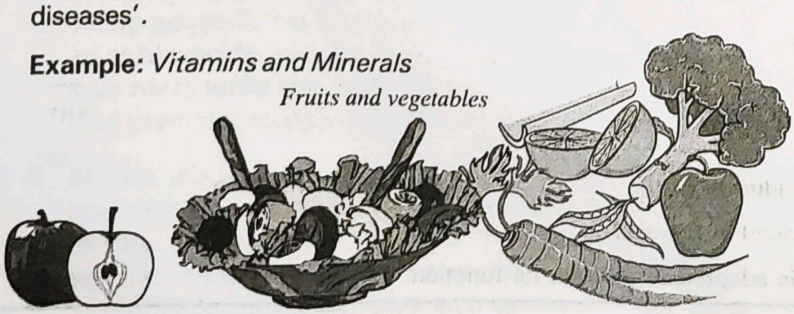
  Example: *Proteins (Milk, meat, egg white, pulses like dals, gram, peas,* etc.)

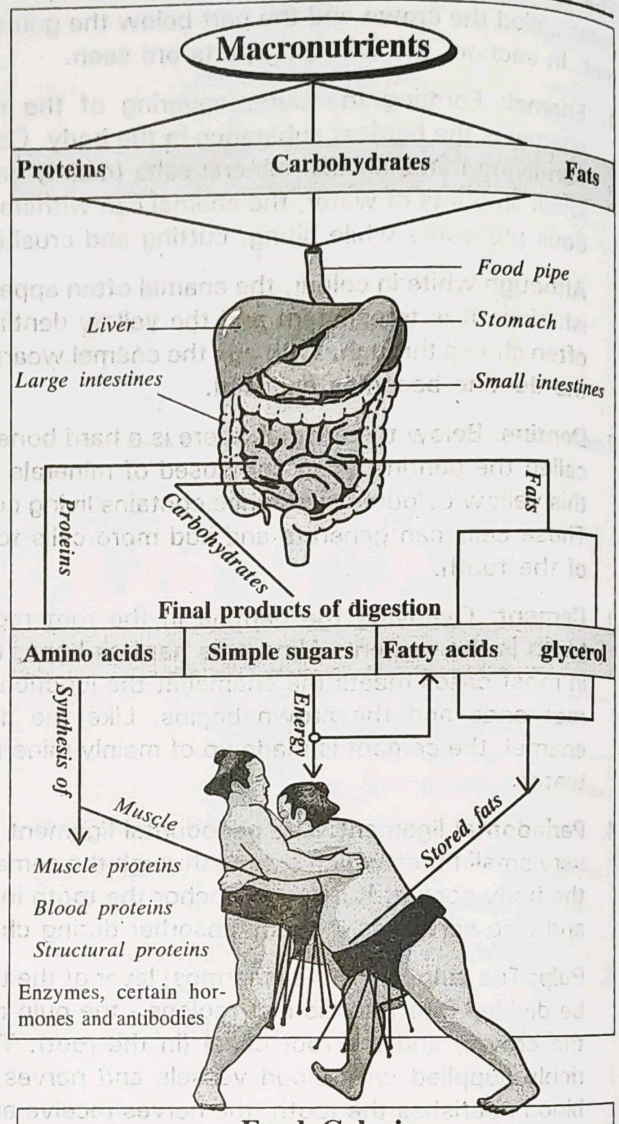


* **Protective foods:** These foods are vital for body functions and the absence of these nutrients result in 'deficiency diseases'.

  Example: *Vitamins and Minerals*

Fruits and vegetables





Food Calorie

The body needs energy to maintain all its functions. The energy in food is measured in units called **food calories.**

A food calorie is the amount of energy required to raise the temperature of 1000 g of water 1°C.

A food calorie is usually referred to simply as a "calorie", but it is actually equal to one **kilocalorie.**

The calorific value of the main classes of food is given below:

Proteins	4.1 kcal
Carbohydrates	4.1 kcal
Fats	9.3 kcal

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Macronutrients

1. **Proteins:** Proteins are made up of chains of nitrogen containing building blocks called **amino acids.** Proteins make up 50% of the solid mass of cells. Adult humans need 20 amino-acids while children need 22 amino-acids to make all the proteins. Amino-acids are grouped under **essential** and **non-essential.**

   * **Essential Amino acids:** These cannot be prepared by the body and have to be ingested with the food.
   * **Non-essential Amino acids:** This group includes necessary amino-acids which occur naturally in the body.

Important Functions of Protein

(i) **Growth and Development: Proteins form cells and tissues.** As such they help build new tissues and replace worn out cells. These are called **structural proteins.**

(ii) **Regulation of Chemical Reactions**

* **Enzymes** (biocatalyst) are proteins which help speed up metabolic processes like digestion and respiration.

  Example: *Pepsin, erepsin*

* **Hormones** are chemical messengers which regulate body functions and result in growth.

  Example: *Insulin, glucagon*

(iii) **Protection: Antibodies** protect the body from infection.

(iv) **Movement and locomotion: Contractile proteins** bring about muscle contraction, and hence, movement.

Example: *Actin, myosin*

(v) **Transport:** Proteins carry different substances in the blood to different tissues.

Example: *Haemoglobin transports respiratory gases.*

(vi) **Source of Energy:** Approximately **4.1 kcal** of energy is released by the oxidation of 1 g of protein. However, the body uses it as the last source of energy when carbohydrates and fats are not available.

Examples of Protein rich Sources

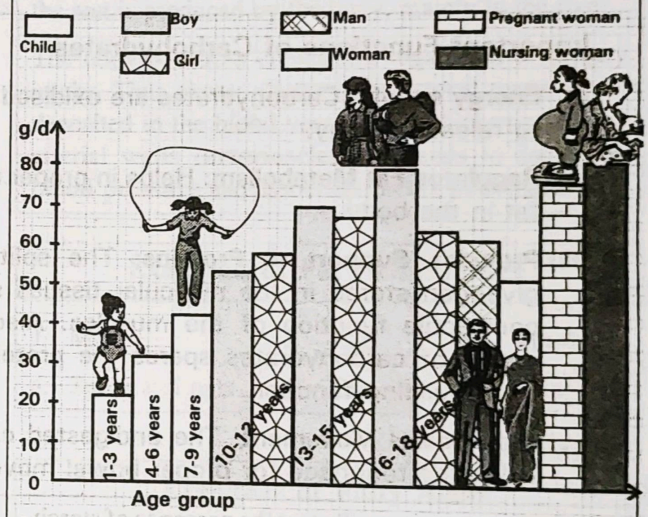
1. **Biologically adequate proteins:** These contain all the essential amino-acids.

   Example: Milk, eggs, meat, caviar, meat, potatoes and mushrooms.

2. **Biologically inadequate proteins:** These lack at least one essential amino-acid.

   Example: Vegetable proteins like beans, peas, grams, lentils, etc.

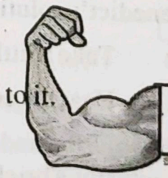
Protein Requirement for different Age Groups



Note: A 12 year old girl needs more proteins than a boy of the same age since the age for maximum growth for girls is around 12 years and for boys it is about 14 years. As such, there is a greater demand for the growth regulating hormones and new tissues among the girls. Boys need growth hormones at age 14 and after.

A pregnant and nursing mother needs more proteins than a normal woman to ensure proper growth development of the foetus, and thereafter of the baby.

Test for Protein



Aim : To test the presence of proteins.

Apparatus : Millon's reagent, test tube, burner, egg white.

Procedure : (i) Take a little egg white in a test tube and add Millon's reagent to it.

(ii) Boil the mixture.

Observation : The egg coagulates and turns pink in colour.

Conclusion : The pink colouration is indicative of protein.

Alternative Test : Proteins stain yellow with nitric acid. Thus, if the egg white is boiled with nitric acid, a yellow colour is observed. If by accident the acid spills on the hand (body) the skin turns yellow.

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2. Carbohydrates

Carbohydrates are compounds of carbon, hydrogen and oxygen which are divided into simple and complex according to their chemical structure.

Carbohydrates (Compounds containing Carbon, Hydrogen, Oxygen)

Simple Sugar

Monosaccharide

1. General formula: $C_6H_{12}O_6$
2. Simplest and smallest molecules of sugar. Consists of 6 carbon atoms into which all complex carbohydrates are converted before they can be absorbed and assimilated by the body.
3. *Example:* Glucose, Fructose, Galactose

Complex Sugar

Disaccharide

General formula: $C_{12}H_{22}O_{11}$

Contains **twice** the number of carbon atoms present in monosaccharides. Also known as double sugars.

Example: Maltose,
Sucrose (cane sugar)
Lactose (milk sugar)

Polysaccharide

General formula: $(C_6H_{10}O_5)_n$

Long chains of monosaccharide molecules. Broken down by the body into two or more sugars when required.

Example: Cellulose, starch (present in plants), Glycogen (in animals) stored in the liver

Important Functions of Carbohydrates

(i) **Energy supply:** Carbohydrates are oxidised in the body to release energy.

(ii) **Regulates Fat Metabolism:** Helps in proper utilisation of fat in the body.

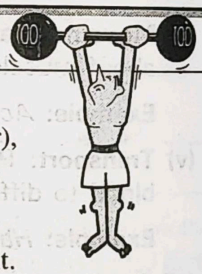
(iii) **Provides Support to Proteins:** The splitting of the glycogen stored in the muscular tissues sustains the contractile function of the muscles. Also, a greater intake of carbohydrates spares the proteins for their body-building function.

(iv) **Aids Bowel Movement:** The undigested cellulose provides the roughage for proper bowel movement.

Points to Note

1. Cellulose, a plant carbohydrate, is not digested by enzymes and is used as roughage.
2. Part of the **starch** and **sugars** ingested is oxidised in respiration to provide energy. Part of it is changed into glycogen or fat and stored.

Tests for Carbohydrates



1. **Aim** : To test the presence of starch.
   Apparatus : Iodine solution, (1 g iodine + 1 g potassium iodide dissolved in 100 cc of distilled water), starch powder, potato or cooked rice, test tubes, burner.
   Procedure : (i) Prepare a starch solution by boiling the starch powder in water.
   (ii) Allow the solution to cool and add a few drops of diluted iodine solution to it.
   Observation : The solution turns dark blue in colour.
   Conclusion : Starch is present.
2. **Aim** : To test the presence of glucose.
   Apparatus : Benedict's solution, test tube, burner, glucose (or crushed apple, grape).
   Procedure : (i) Take a little glucose in a test tube and prepare a solution by adding to it some Benedict's solution.
   (ii) Heat the solution and bring to boil.
   Observation : The solution undergoes a colour change ranging from transparent blue, to opaque green to yellow and eventually a brick red precipitate is formed.
   Conclusion : Formation of the red precipitate indicates presence of glucose.

Note: Sucrose, a disaccharide fails to react with Benedict's solution unless boiled with dilute hydrochloric acid and neutralised with sodium bicarbonate.

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3. Fats (Lipids)

Fats are composed of fatty acids associated with carbon, hydrogen and oxygen forming long molecules. Depending on their hydrogen content, fats may be either saturated or unsaturated.

* **Saturated Fats:** These cannot hold any more hydrogen and are solids at room temperature. For example, *ghee*.
* **Unsaturated Fats:** These are capable of holding more hydrogen and are liquids at room temperature. For example, oil.

By a process called **hydrogenation**, unsaturated fats can be converted into saturated fats.

Oil + hydrogen $\xrightarrow{\text{catalyst (Ni)}}$ ***ghee***

The building blocks of fat are fatty acids, attached to a small organic molecule called glycerol.

Fatty acid + glycerol = Fat

Ingested fats are chemically different from fats of body tissues. Dietary fats are therefore converted by enzymes (example, lipase) into **glycerol** and **fatty acids** from which specific body fat is produced.

Important Functions of Fats

(i) **Energy Source:** Fats are the chief energy producers with a calorific value of **9.3 kcal of heat.**

(ii) **Structural role:** Lipids are structural constituents of the cytoplasm, nucleus, mitochondria, biological membranes and are involved in the formation and regeneration of cell and tissue structures.

(iii) **Insulation:** Fats stored in the body tissues (subcutaneous fat) insulates the body and helps it to maintain a regular temperature.

(iv) **Padding:** Fats deposited around the internal organs like the kidneys, liver, etc. cushions the vital organs.

(v) **Transport of soluble vitamins:** Fats are solvents for certain vitamins like vitamins A, D, E and K.

(vi) **Reserve Food:** Fats are stored in the body for subsequent use.

Cholesterol

All natural fats are a mixture of **saturated** and **unsaturated** fatty acids. Generally, animal fats are more highly saturated than vegetable fats.

Exceptions: Poultry and fish oils are high in unsaturated fat while coconut oil (vegetable oil) is high in saturated fat.

Unsaturated fats are more reactive than saturated fats (due to double bonds) and hence easier to digest. On the other hand, saturated fats, being stable, tend to get stored in the body. As such they produce more blood cholesterol than unsaturated fats.

Cholesterol is a complex waxy substance that is an essential component of the walls of the body cell. Only 15% of the blood cholesterol comes from the diet while the rest is produced by the body, mainly in the liver.

The body produces cholesterol regardless of dietary intake. Thus **excess dietary cholesterol** tends to get deposited in the blood vessel. The thickening of the arterial walls **(arteriosclerosis)** leads to increased **blood pressure** and associated **heart problems.**

Examples of Fat rich Sources

1. Milk	2. Egg	3. Meat
4. Seeds and nuts	5. Oils	6. Butter

Examples of Fatty Acids

1. Butyric acid : Present in butter
2. Palmitic acid : Present in palm oil
3. Oleic acid : Present .in unsaturated plant and animal fat

Fatty acids are necessary for good health. They also find use in the manufacture of soap, e.g., stearic acid.

Test for Fats

Aim : To test the presence of fats.

Apparatus : Sudan Black (dye), olive oil, test tube.

Procedure :
(i) Take a little water in a test tube and add to it about 4 drops of Sudan Black.
(ii) Add to the above solution a few drops of olive oil.
(iii) Shake the test tube until an emulsion forms, and allow it to stand.

Observation : Small droplets (coloured with the dye) are seen on the surface of the liquid.

Conclusion : Fat is present and is recognised as fat droplets.

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Exercise 2

1. a. What are nutrients? Name the three macronutrients.
   b. Give two examples of foods rich in each of the macronutrients named in (a).
2. a. What are micronutrients?
   b. Name the two micronutrients present in our food.
3. **Name the food group associated with the following functions:**
   (i) Providing energy (ii) Growth and repair
4. **Name the food groups of which the following are the end products of digestion:**
   (i) Amino acids (ii) Fatty acids and glycerol (iii) Simple sugars
5. What is a kilocalorie? Name the class of food that has the highest calorific value.
6. a. What are proteins?
   b. Distinguish between the following pairs:
      (i) Essential amino acids and non-essential amino acids.
      (ii) Biologically adequate proteins and biologically inadequate proteins.
7. a. Why does a 12 year old girl need more proteins than a boy of the same age?
   b. Why does a pregnant woman need more proteins than a non-pregnant woman?
8. **Explain the role of proteins in:**
   (i) Regulating chemical reactions in the body
   (ii) Bringing about growth and repair
   (iii) Protecting the body
   (iv) In movement and locomotion
   (v) As a source of energy
9. Describe a simple test to identify the presence of proteins.
10. What are carbohydrates?
11. Give the general formula and one example of each:
    (i) A monosaccharide (ii) A disaccharide (iii) A polysaccharide
12. State the important functions of carbohydrates.
13. What is the ultimate fate of the following carbohydrates ingested in the human body?
    (i) Cellulose (ii) Starch
14. **Name a reagent used to identify:**
    (i) Starch (ii) Glucose
15. What are fats? Distinguish between saturated and unsaturated fats and give one example of each.
16. Why are fats considered the chief energy producers in our body?
17. Mention three functions of fats, other than as an energy source.
18. a. What is cholesterol?
    b. Give an example of a food source that would produce blood cholesterol.
    c. Mention the health problems associated with intake of excess dietary cholesterol.
19. Name three fatty acids and mention the food in which each is present.
20. Give a simple test to identify the presence fats in foods.
21. Explain why the skin turns yellow if nitric acid spills onto it.

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Role of Micronutrients

1. Minerals

Minerals are inorganic substances that the body needs for the following:

(i) Forming bones, teeth, blood cells.

(ii) Assisting in the chemical reactions of the cells.

(iii) Regulating body fluids.

The essential minerals, i.e., the ones the body needs to survive are divided into two groups: the **macroelements** and the **microelements** (trace elements). It may be noted that minerals are not destroyed by cooking.

The table overleaf gives a complete account of the role of minerals in our body.

Mineral Groups

* **Macroelements:** These are required in amounts exceeding 10 g per day.
* **Microelements:** These are required in almost negligible quantities.

The table on pages 140-141 summarizes the best sources and role of minerals

2. Vitamins

Apart from major nutrients and mineral salts, there are some additional factors which are vital to life. These essential compounds are called **vitamins**.

Vitamins are compounds of various chemical nature which are easily destroyed on storage, (especially in daylight) or prolonged boiling. For best vitamin value, food should be eaten in its freshest possible state. In cases where the water soluble vitamins (the B vitamins) tend to wash out of the food, the cooking liquid should be used as stock and in gravies instead of discarding it. The main source of vitamins for humans is food of vegetable origin.

Vitamins B_6, B_{12}, B_3 and K are synthesized in the human body by intestinal bacteria. Therefore, patients under the treatment of sulphanilamide and antibiotics that destroy the intestinal flora must be simultaneously compensated with these vitamins.

Certain vitamin reserves (A, C, B_6) that are stored in the body can suffice for several months. Other vitamin reserves are limited and have to be replenished. Vitamins are divided into two large groups: **water soluble** and **fat soluble.**

Nomenclature of Vitamins

Earlier, vitamins were assigned alphabets such as A, B, C, D etc. However, the discovery of more new vitamins made their nomenclature complicated and warranted the use of their chemical names.

Example:	**Old name**	**New name**
	Vitamin B_1	Thiamine
	Vitamin B_2	Riboflavine
	Vitamin B_3	Pantothenic acid
	Vitamin B_6	Pyridoxine

Vitamins

Water soluble	:	B, C.
Fat soluble	:	A, D, E, K

Major Functions of Vitamins

Vitamins are neither building materials nor energy donors, but are required by the body for various purposes. They help to perform the following functions:

(i) Process other nutrients

(ii) Regulate the nervous system

(ii) Form genetic material, proteins, red blood cells, and hormones.

The table on pages 142-143 summarize the best sources and role of the essential vitamins.

Note

Diseases that result from nutritional vitamin deficiencies are known as **avitaminosis** or **polyavitaminosis** (deficiency of several vitamins).

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Mineral	Best Food Resouces	Role in Health
Macrominerals		
Calcium	Milk and dairy products, tinned sardines with bones, green leafy vegetables, sesame seeds.	Builds bones and teeth and keeps them strong; vital to nerve transmission, blood clotting and muscle functions.
Chloride	Table salt (sodium chloride) and foods containing it.	Maintains the fluid and electrolyte balance in the body. Vital for stomach acid formation.
Magnesium	Wholegrain cereals, wheatgram, pulses, nuts, sesame seeds, dried figs and green vegetables.	Important constituent of bones and teeth; assists in nerve impulses; important for muscle contraction.
Phosphorus	Present in all plant and animal protein, such as milk, cheese, red meat and poultry, fish and seafood, nuts, seeds and whole grain.	Helps to form and maintain healthy bones and teeth; needed to release energy in cells; essential for absorption of many nutrients.
Potassium	Avocados, fresh and dried fruit, seeds and nuts, bananas, citrus fruit, potatoes and pulses.	Maintains the fluid and electrolyte balance within cells, keeps heartbeat regular and maintains normal blood pressure. Essential for the transmission of all nerve impulses.
Sodium	Table salt (sodium chloride), tinned fish, processed meats and yeast extracts.	Works with potassium to regulate fluid balance; essential for nerve and muscle function.
Microminerals		
Alumunium	Not applicable: the ingestion of aluminium should be avoided where possible.	No known biological function in the body.
Chromium	Red meat and liver, egg yolk, seafood, wholegrain cereals, molasses and cheese.	Important for regulation of blood sugar levels; helps to regulate blood cholesterol levels.
Copper	Offal, shellfish such as oysters, nuts and seeds, mushroom and cocoa.	Needed for bone growth and connective tissue formation. Helps the body to absorb iron from food. Present in many enzymes which protect against free radicals.
Fluoride	Toothpaste, tap water and tea.	Protects against tooth decay.
Iodine	Seaweed, seafood and iodised table salt.	Vital part of hormones secreted by the thyroid gland.
Iron	Offal, lean meat, sardines, egg yolk, dark green leafy vegetables (depending on soil).	Essential component of haemoglobin and many enzymes involved in energy metabolism.
Manganese	Nuts, cereals, brown rice, pulses, and wholegrain bread.	Vital component of various enzymes involved in energy production; helps to form bone and connective tissue.
Molybdenum	Offal (especially liver), yeast, pulses, whole grains and leafy vegetables (depending on soil).	Essential component of enzymes involved in the production of DNA and RNA; may fight tooth decay.
Selenium	Meat and fish, dairy foods such as butter, Brazil nuts, avocadoes and lentils.	Antioxidant mineral: protects cell against free radical damage. Vital for normal sexual development.
Sulphur	Protein from animal and vegetable sources.	Components of two essential amino acids which help to form many proteins in the body. Present in every cell.
Zinc	Oysters, red meat, peanuts and sun flower seeds.	Essential for normal growth, reproduction and immunity. Aids the action of many enzymes.

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Role of Minerals

Daily Requirements		Symptoms of Deficiency	Symptoms of Excess
Male	Female		
700 mg	700 mg	Muscle weakness, back pain, soft and brittle bones, fractures and **osteoporosis.**	None: Surplus calcium is not absorbed by the body but simply excreted.
2500 mg	2500 mg	Deficiency does not occur on a normal diet.	None: excess chloride is excreted by the kidneys.
300 mg	300 mg	Apathy, weakness, cramps and muscle tremors (tetany) which lead to convulsions.	No reported symptoms.
550 mg	550 mg	Deficiency is rare but may be induced by prolonged use of antacids.	Excessive intake can affect the body's ability to use calcium and inhibit the absorption of magnesium.
3500 mg	3500 mg	Apathy, weakness, confusion and extreme thirst. In several cases, there may be abnormal heartbeat and other heart and respiratory problems.	May cause lethargy, slow heartbeat, paralysis and heart failure.
1600 mg	1600 mg	Deficiency is rare but can lead to low blood pressure, dehydration and muscle cramps.	Fluid retention, high blood pressure which can lead to strokes; heart and kidney failure.
None	None	None	Has been linked with Alzheimer's disease; may cause hip problems in the elderly.
25 micrograms	25 micrograms	May cause glucose intolerance and raised blood cholesterol levels.	No adverse symptoms reported.
1.2 mg	1.2 mg	Deficiency is rare, and usually occurs only in premature babiess or in infants with malabsorption problems.	High intakes are unlikely but could be toxic, causing liver and kidney damage.
There is not set dietary requirement		Tooth decay.	Weak, mottled teeth, brittle bones.
140 microgms	140 microgms	**Goitre;** maybe coarse skin and hair; apathy.	High intake can cause hyperthyroidism.
8.7 mg	14.5 mg	Shortness of breath, fatigue, iron deficiency **anaemia**, reduced resistance to infection.	Iron poisoning occurs when children mistake iron supplements for sweets.
1.4 mg	1.4 mg	No reported symptoms.	None: excess manganese is safely excreted by the body.
50-400 micrograms	50-400 micrograms	Deficiency is virtually unknown.	High intakes may induce copper deficiency.
75 microgms	60 micrograms	Rare; could stunt growth, delay sexual development and reduce fertility.	Hair loss, skin depigmentation, fatigue.
There is no set dietry requirement.		Deficiency is unknown.	None
9.5 mg	7 mg	Loss of appetite; in adolescents, impaired growth and development; poor immunity.	Remote unless inadvertently overdosing on self-administered supplements.

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Vitamin	Best Food Resouces	Role in Health
A (from retinol in animal foods or from beta carotene in plant foods)	Retinol: liver, oily fish, egg yolk, butter, cheese. Beta carotene: carrots, squash, apricots, cantaloupe melon and green leafy vegetables. [6 mcg beta carotene are needed to make 1 mcg of Vitamin A]	Essential for growth and cell development, vision and immune function. Maintain the health of the skin and mucous membranes such as the lining of the respiratory and urinary tracts. Carotenes may act as important antioxidants in the body.
Thiamine (B_1)	Pork, liver, heart, kidneys, fortified white bread, fortified breakfast cereals, potatoes, nuts and pulses.	Needed to obtain energy from carbohydrates, fats and alcohol; prevents the build-up of toxic substances in the body which may damage the heart and nervous system.
Riboflavin (B_2)	Milk, yoghurt, eggs, meat, poultry, fish and fortified breakfast cereals.	Needed to release energy from food and for the functioning of vitamin B_6 and niacin.
B_6 (pyridoxine)	Lean meat, poultry, fish, eggs, wholewheat bread and cereals, nuts, bananas, yeast extract and soya beans.	Helps to release energy from proteins; important for immune function, the nervous system and the formation of red blood cells.
Niacin (nicotinic acid)	Lean meat, poultry, pulses, potatoes, fortified breakfast cereals and nuts.	Needed to produce energy in cells and to form neurotransmitters. Helps to maintain healthy skin and an efficient digestive system.
Pantothenic acid	Contained in all meat and vegetable foods, particularly liver, dried fruit and nuts.	Helps to release energy from food. Essential to the synthesis of cholesterol, fat and red blood cells.
Biotin	Present in almost all foods, particularly liver, peanut butter, egg yolk and fortified foods such as yeast extracts.	Needed to release energy from food. Important in the synthesis of fat and cholesterol.
Folate (Folic acid)	Green leafy vegetables, liver, Brussels sprouts, broccoli, pulses, fortified breakfast cereals and bread.	Required for cell division and the formation of DNA, RNA and proteins in the body. Extra needed before conception and in pregnancy to protect against neural tube defects.
B_{12} (cyanocobalamin)	Foods of animal origin such as meat, poultry, fish, eggs and dairy products, as well as certain fortified breakfast cereals.	Vital for making DNA, RNA and myelin - the white sheath that surrounds nerve fibres. Also needed for cell division and the transportation of folate into cells.
C (ascorbic acid)	Fruits and vegetables, particularly citrus fruit, strawberries, kiwi fruit, peppers, blackcurrants and potatoes.	Needed to make collagen (a protein essential for healthy gums, teeth, bones, cartilage and skin) and neurotransmitters such as noradrenaline and serotonin. Important as an antioxidant in the body; aids absorption of iron from plant food.
D (calciferols)	Fish liver oils, eggs, fortified margarines, tuna, salmon, and sardines.	Needed to absorb calcium and phosphorus for normal formation of bones and teeth.
E (tocopherols)	Vegetable oils, wheatgerm, nuts, seeds and margarine.	Helps to prevent oxidation by free radicals of polyunsaturated fatty acids in cell membranes and other tissues.
K (phylloquinone menaquinone)	Green leafy vegetables especially green cabbage, broccoli and Brussels sprouts.	Essential in forming certain proteins and needed for normal blood clotting.

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Role of Vitamins

Daily Requirements		Symptoms of Deficiency	Symptoms of Excess
Male	Female		
700 mcg (of Vitamin A)	600 mcg (950 mcg in lactation)	Causes **xerophthalmia**:poor night vision, increases risk of infection, respiratory disorders; eye damage which in extrene cases can lead to blindness.	Drowsiness, hair loss, headaches and vomiting, liver and bone damage. Increased risk of abortion and defects in newborn babies. Excess carotenes may cause the skin to become yellow.
1 mg	0.8 mg	Causes **beri-beri**: appetite loss, mental confusion, swelling of the limbs, loss of sensation, nervous disorders, muscle weakness and an enlarged heart.	No known symptoms, as any excess thiamin is cleared by the kidneys.
1.3 mg	1.1 mg	Dry, cracked lips, inflamed, bloodshot eyes, dermatitis, mild anaemia.	No known toxicity; excess is normally excreted as bright yellow urine.
1.4 mg	1.2 mg	Deficiency in adults is rare but may be induced by antifungal and antitubercular drugs. Symptoms include **anaemia**, depression and confusion.	Nerve damage. High doses over a long period lead to loss of sensation and function in the hands and feet.
17 mg	13 mg	Causes **Pellagra.** Fatigue, depression, pigmented skin rash (more likely when exposed to sunlight), dermatitis, diarrhoea and in advanced cases, dementia.	High doses of nicotinic acid supplements may result in 'flushing' of the skin and liver damage.
3-7 mg	3-7 mg	Deficiency is extremely rare and may lead to numbness and tingling in the toes.	No reported symptoms.
10-200 mcg	10-200 mcg	Deficiency is unknown on a normal diet but can be induced if raw egg whites are eaten regularly. Symptoms include dermatitis and hair loss.	No reported symptoms.
200 mcg	200 mcg (400 mcg in pregnancy)	**Megaloblastic anaemia**, wasting of the gut leading to malabsorption of nutrients. Linked with neural tube defects in foetus.	Excess folate is not toxic, but it may mask vitamin B_{12} deficiency and trigger convulsions in epileptics.
1.5 mcg	1.5 mcg	Fatigue, **megaloblastic anaemia**, pins and needles and loss of sensation in limbs; degeneration of the nervous system.	No reported symptoms.
40 mg (smokers: at least 80 mg)	40 mg (smokers: at least 80 mg)	Fatigue, appetite loss, aching joints. sore gums, scaly skin. Slow healing of wounds and consequent increased susceptibility to infection. Severe deficiency can cause **scurvy** mental disorders and internal haemorrhages which may lead to anaemia.	Surplus Vitamin C is safely excreted in the urine. Megadoses may, however, lead to kidney stones in susceptible people. Megadoses may also cause headaches and sleep disturbance, and should not be taken by pregnant women.
Enough vitamin D is made when the skin is exposed to sunlight. People who are confined indoors require about 10mcg from the diet.		Muscle weakness and tenseness; softening of the bones causing bone pain and fractures **(osteomalacia)**. In children, leads to deformation of the skeleton **(rickets)**.	High levels of calcium in the blood lead to calcium deposits and irreversible damage in soft tissue such as the heart, lungs and kidneys.
At least 4 mg	At least 3 mg	Occurs only in people who cannot absorb fat and in premature babies. Symptoms include haemolytic anaemia and nerve damage.	Vitamin E is not highly toxic but high doses may cause Vitamin K deficiency.
70 mcg	65 mcg	In extreme cases a deficiency reduces prothrombin (a coagulation agent) so impairing clotting of the blood. In adults deficiency is usually the result of disease or drug therapy.	There may be a link between new-born babies who have been injected with vitamin K and a raised incidence of leukaemia in childhood.

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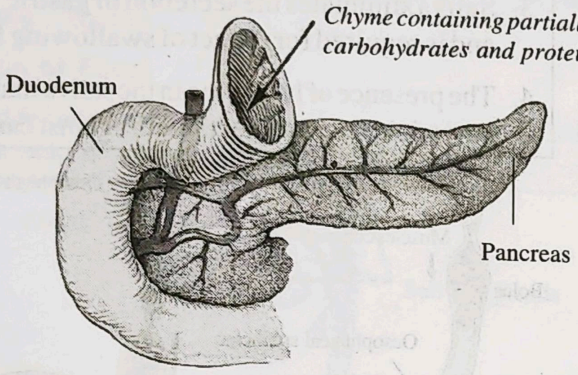
3. **The Small Intestine:** The contraction of the stomach muscles cause the chyme to empty into the upper part of the small intestine called the **duodenum.**

a. **Duodenum:** This short, folded or looped upper region of the small intestine measures about 25 cm. The **bile duct** from the liver and the **pancreatic duct** from the pancreas pour their fluids (bile and the pancreatic juice) into the duodenum by the **common bile duct.** The pancreatic juice contains the enzymes **pancreatic amylase, trypsin and steapsin.**



Part of the Alimentary canal showing the association of the Pancreas and the Duodenum

Digestion in the Duodenum

The pancreatic juice contains three kinds of enzymes.

1. **Amylopsin:** Converts starch into maltose.
2. **Trypsin:** Digests the remaining proteins, proteoses and peptones into peptides and amino acids.
3. **Steapsin** (lipase): Splits up the emulsified fat into fatty acid and glycerol.

b. **Jejunum:** The duodenum continues downwards as a short region, about 2.5 metres in length called the jejunum. No chemical digestion takes place here.

c. **Ileum:** The ileum is a long, narrow highly coiled tube about 3.6 metres in length which in an adult secretes 2 to 3 litres of intestinal juice.

The final stage of the mechanical and chemical processing of food takes place here. The **completely digested liquid** in the ileum is called **chyle.**

Role of Bile

Bile is a yellowish green fluid containing large amounts of sodium bicarbonate and bile pigments like **biliverdin** and **bilirubin** (formed by the breakdown of the dead or worn out red blood cells).

Bile is **produced by the liver** and **stored in the gall bladder.**

Functions of Bile

1. Provides an alkaline medium for the intestinal enzymes to act as these enzymes function only in an alkaline environment.
2. Emulsifies fat i.e., breaks up the fat droplets into tiny bits. This provides a larger surface area for enzyme activity.
3. Various metabolic wastes are eliminated from the blood stream in the bile. This excretory function distinguishes bile from other digestive substances.

Digestion in the Ileum

1. Erepsin	:	Converts proteoses, peptones and peptides into amino-acids.
2. Maltase	:	Acts upon maltose and breaks it up into glucose.
3. Sucrase	:	Converts sucrose into glucose and fructose.
4. Lactase	:	Converts lactose into glucose and galactose.

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Role of Liver

The liver is the body's largest gland weighing about 1500 g. It is reddish brown in colour, consisting of a large right lobe and a smaller left lobe. Each lobe is made up of thousands of lobules, penetrated by the branches of the hepatic and portal veins.

1. The liver produces bile which is essential for lipid metabolism.
2. It converts and stores excess glucose as glycogen, thereby regulating the amount of sugar in the blood.
3. Nitrogen is freed from excess amino acids (by deamination) in the liver and converted into **urea** which is eliminated from the body as part of urine.
4. The liver stores nutrients (fats, glucose), vitamins (A, D, E, K), trace elements (iron, copper) and excess water. By storing excess water, the liver regulates the blood volume.
5. The liver produces red blood cells in the embryo. In adults the red blood cells are destroyed in the liver.
6. Toxic metabolites are rendered harmless in the liver and excreted.
7. **Fibrinogen,** an important factor in blood clotting, is produced in the liver.
8. **Heparin,** an anticoagulant is also produced in the liver.
9. The liver produces heat by cellular metabolism.

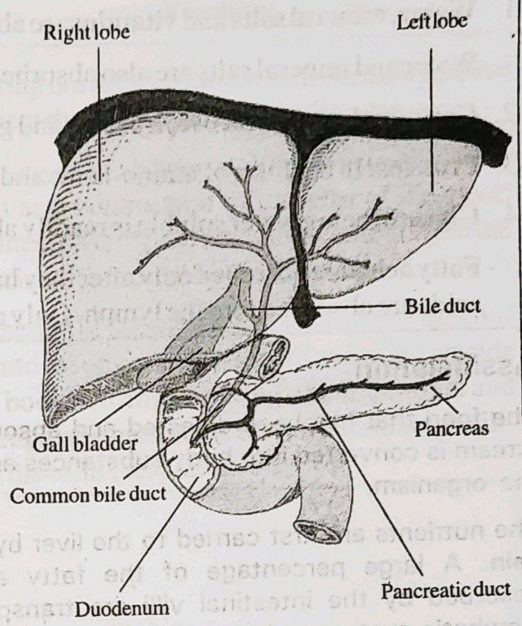


Diagram showing the association of Liver, Pancreas and the Duodenum

Absorption of Nutrients

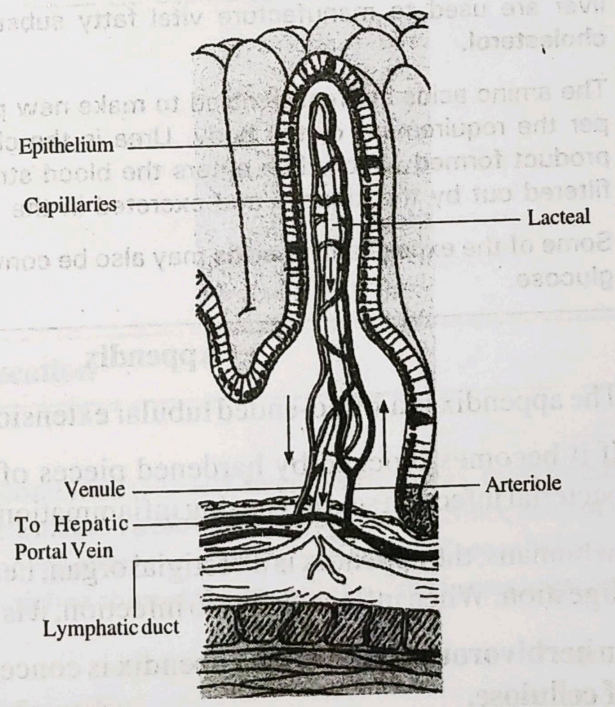
Absorption is a universal physiological process by which various substances pass across a layer of cells into the internal environment of the body.

Due to absorption, the body is supplied with all the nutrients it requires for its activities. Absorption occurs in all parts of the digestive tract, but the main site of absorption is in the **ileum.**

Accordingly, the ileum is adapted to fulfill its role in absorption.

1. The ileum is long and coiled (about 4 metres) providing a larger surface area in contact with food. Also, the food remains in it for a period sufficiently long enough to ensure thorough digestion.
2. It is narrow, allowing intimate contact of the food with its inner walls. Also the slow movement of food along the narrow passage permits better absorption.
3. The inner wall of the ileum consists of a single-celled layer of epithelium which enables the molecules of nutrients to pass through with ease.
4. The inner lining of the ileum is thrown into a number of finger-like projections called villi (singular: villus). These increase the surface area considerably, (about 8 times greater than the outer body surface) enhancing the rate of absorption.

The food remains in the small intestine for nearly four hours.



Section through a single Villi highly Magnified

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Absorption of Nutrients

1. **Water, mineral salts** and **vitamins** are absorbed into the blood throughout the length of the small intestine.

   Water and mineral salts are also absorbed in the stomach and the large intestines.

2. **Carbohydrates:** Glucose, fructose and galactose are absorbed in the ileum.
3. **Proteins:** In the form of amino-acids and simple peptides, proteins are absorbed in the ileum.
4. **Glycerol** being water soluble is readily absorbed.

   Fatty acids are absorbed only after they have interacted with bile salts to form complex compounds. Most of the fatty acids are absorbed into the lymph. Only about 30% enters the blood.

Assimilation

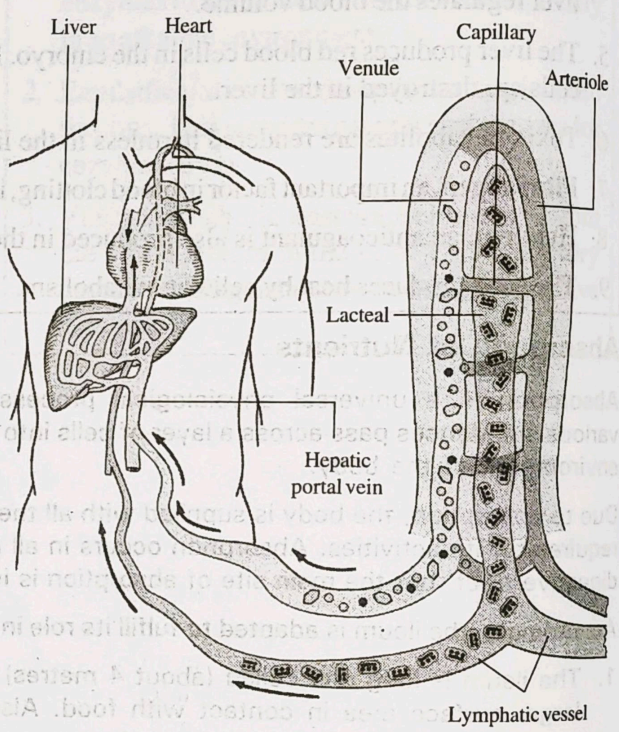
The food that has been digested and absorbed into the blood stream is converted into body substances and becomes part of the organism.

The nutrients are first carried to the liver by the **hepatic portal vein**. A large percentage of the fatty acids and glycerol absorbed by the intestinal villi are transported through the lymphatic system to be emptied into the heart.

In the liver, the following metabolic conversions take place:

1. Glucose from the intestines is converted into insoluble **glycogen** and stored in the liver itself. When required by the body as an energy source, the liver reconverts the glycogen into glucose and returns it to the blood. Excess glucose is converted and transported to adipose cells around the body, to be stored as fat.
2. Some of the fatty products of digestion that arrive in the liver are used to manufacture vital fatty substances like **cholesterol**.
3. The amino acids are reassembled to make new proteins as per the requirement of the body. Urea is the chief waste product formed which then enters the blood stream to be filtered out by the kidneys and excreted in the urine.

   Some of the excess amino acids may also be converted into glucose.



Movement of Nutrients towards Liver and Heart

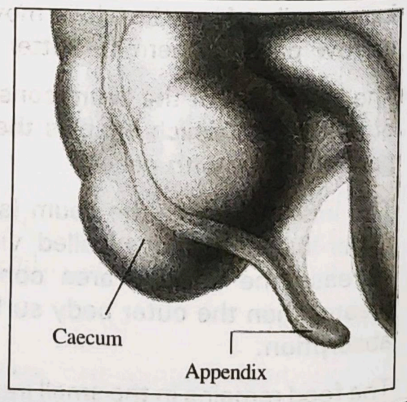
Appendix

The appendix is a blind-ended tubular extension of the caecum.

If it becomes blocked by hardened pieces of faeces or fruit stones, bacterial infection sets in causing inflammation and abdominal pains.

In humans, the appendix is a vestigial organ, i.e., it has no role to play in digestion. When inflamed, due to infection, it is surgically removed.

In **herbivorous animals,** the appendix is concerned with the **digestion of cellulose.**



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Egestion

The undigested food, consisting mainly of cellulose combined with left-over gastric juices, bile contents, sloughed off cells from the gut lining and dead and decaying bacteria makes up the brown faecal matter. Since most of the water has been absorbed the faeces is a semi-solid mass which is moved along the **large intestine** by peristalsis.

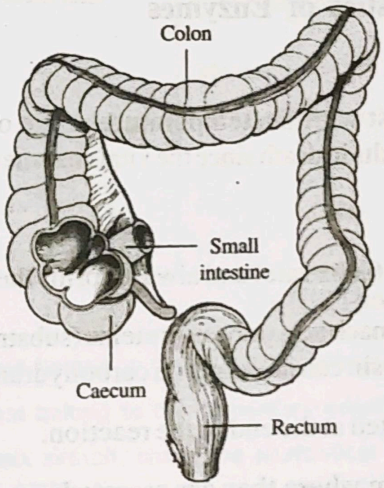
The large intestine is divided into three main portions - the **caecum,** the **colon** and the **rectum** totalling about 2 metres in length.

a. Caecum

The junction of the small intestine and the large intestine is called caecum.

b. Colon

It is the region of the large intestine, measuring 5 cm in width and about 1.5 m in length. It runs up from the caecum (ascending colon), horizontally across the top beneath the liver (transverse colon) and finally down the left side (descending colon) to turn back toward the midline in an S-shaped bend before opening out into the next region - the rectum.



c. Rectum

The final region of the gut is the 15 cm long rectum. It is a distensible bag-like structure which ends in a 5 cm long anal canal. The anal canal is guarded internally as well as externally by means of sphincter muscles. The internal sphincter remains contracted and prevents the leakage of faecal material through the anus. The periodical elimination of faeces from the rectum is known as **defaecation.**

Vomiting

Vomiting is a reflex action which normally serves to protect the body against harmful substances.

Vomiting is an antiperistaltic movement which begins as a contraction of muscles of the small intestines, pushing the intestinal contents into the stomach via the opened pyloric sphincter.

Contraction of the stomach muscles force the contents into the oesophagus, mouth and to the outside of the body. During vomiting, the abdominal and diaphragmatic muscles forcefully contract, facilitating the reflex response.

Functions of the Colon

1. It promotes water absorption.
2. The bacteria present help to produce and facilitate the absorption of several important chemicals into the body especially vitamin K.
3. Formation of faeces take place in the colon.

Faeces and Defaecation

Faeces

The food that cannot be digested, consisting mainly of cellulose combined with left-over gastric juices, bile contents, sloughed off cells from the gut lining and dead and decaying bacteria makes up the brown faecal matter. Since most of the water has been absorbed the faeces is a semi-solid mass which is moved along the colon by peristalsis. Faeces held in the colon and rectum are a favoured breeding ground for bacteria. Almost one-third of the dry weight of the faeces is bacteria.

Defaecation

The periodical elimination of faeces from the body is known as **defaecation.**

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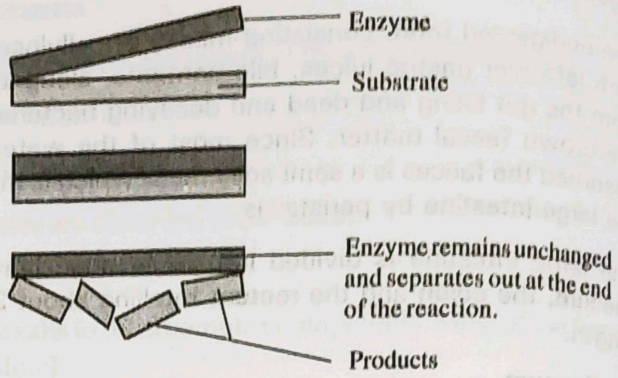
What are Enzymes?

The word enzymes is derived from two Greek words meaning **"in yeast"** since early scientists studied reactions caused by yeast enzymes.

Enzymes are **biocatalyst**, that is, chemical substances present in the body which greatly speed up (almost a million times) the rate of the physio-chemical reactions. At the end of the reaction, the enzyme remains unchanged and separates from the product of the reaction.

Without enzymes, reactions would occur very slowly or not at all, making life almost impossible. All living cells make enzymes, but enzymes themselves are non-living.



A Diagrammatic Representation of the Action of Enzymes

Characteristics of Enzymes

1. All enzymes are proteins.
2. **Enzymes are destroyed by heating** and act best within a temperature range of **35°C to 40°C.** Thus, an increase in body temperature to 42°C (108°F) results in death since the vital enzymes in the cells are destroyed.
3. **Enzymes are specific in their action.**

   A particular enzyme acts only on one substance (substrate) and always forms the same end-products.

   Example: The enzyme pepsin secreted in the stomach acts only on proteins (substrate) and always forms the same end-products peptones and proteoses. Pepsin can never act on carbohydrates or fats.
4. **Enzymes can be reused** since they are regenerated at the end of the reaction.
5. **Enzymes act on substrate close to the site from where they are secreted.**

   Example: Pepsin is secreted in the stomach and acts on the proteins present in the stomach.
6. **Enzymes function best only at a particular pH.**

   The pH of a solution is indicative of its acidity or alkalinity.

   Example: Pepsin requires an acidic medium while trypsin (secreted by the pancreas) functions in an alkaline environment.
7. Enzymes only speed up the rate of the reaction.

Additional Uses of Enzymes

1. Some detergents contain enzymes that break down protein matter such as perspiration that cause stains.
2. Enzymes are used in the manufacture of antibiotics, beer, bread, cheese, vinegar, vitamins, etc.
3. Enzymes in certain medicines are used to clean wounds and dissolve blood clots.
4. Diseases like anaemia, leukaemia, heart and liver ailments are often diagnosed by measuring the amount of various enzymes present in blood and other body fluids.

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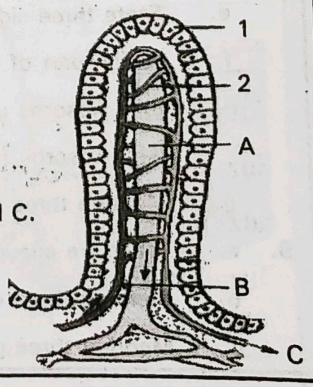
A Summary of the Stages in Digestion

Part of Alimentary Canal	Secretion	Enzyme secreted	Substrate	Product of Digestion
Mouth	Saliva	Ptyalin	Starch	Maltose
Oesophagus	None	None	None	None
Stomach	Gastric juice and hydrochloric acid	Pepsin in adults	Proteins	Proteoses and peptones
		Renin in children	Caseinogen	Casein
Duodenum	(i) Bile	None	Fats	Emulsified fat
	(ii) Pancreatic juice	1. Amylopsin	Starch	Maltose
		2. Trypsin	Proteins	Proteoses, peptones, peptides, amino acids
		3. Steapsin (lipase)	Fats	Fatty acids and glycerol
Ileum	Intestinal juice	Erepsin (Peptidase)	Proteins and peptides	Amino acids
		Maltase	Maltose	Glucose
		Sucrase (Invertase)	Sucrose	Glucose and Fructose
		Lactase	Lactose	Glucose and Galactose
Colon	None	None	None	Absorbs water and mineral salts
Rectum	None	None	None	Temporarily stores undigested food

Exercise 4

1. (i) Name all the parts that belong to the digestive system only.
   (ii) Name all the parts that belong to the alimentary canal only.
2. (i) With the help of a neat sketch, show the anatomical relation between the liver, gall bladder, pancreas and the duodenum. Label the parts.
   (ii) Explain the function of the liver, gall bladder and pancreas with respect to digestion taking place in the duodenum.
3. **Explain why:**
   (i) The ileum is long, narrow, coiled and internally furrowed and covered with numerous finger-like projections.
   (ii) A piece of bread left in the mouth for a while tastes sweet.
4. **Name one enzyme responsible for each of the following conversions:**
   (i) Proteins/peptides → amino acid
   (ii) Fats → fatty acid
   (iii) Proteins → proteoses, peptones, amino acid
   (iv) Lactose → glucose, galactose
   (v) Starch → maltose
5. What is meant by peristalsis?
6. (i) In the diagram given alongside, label parts 1 and 2.
   (ii) State two differences in the chemical composition of the fluids flowing through B and C.
   (iii) Name the main chemical constituent present in A?
   (iv) What is the eventual fate of the substance named in A?
   (v) State one difference between chyme and chyle.



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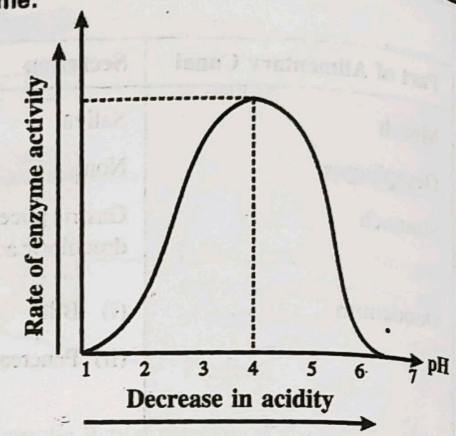
7. The graph shows the effect of pH on the activity of a certain digestive enzyme.



(i) At what pH is the activity of the enzyme highest?

(ii) At what pH does the activity of the enzyme virtually stop?

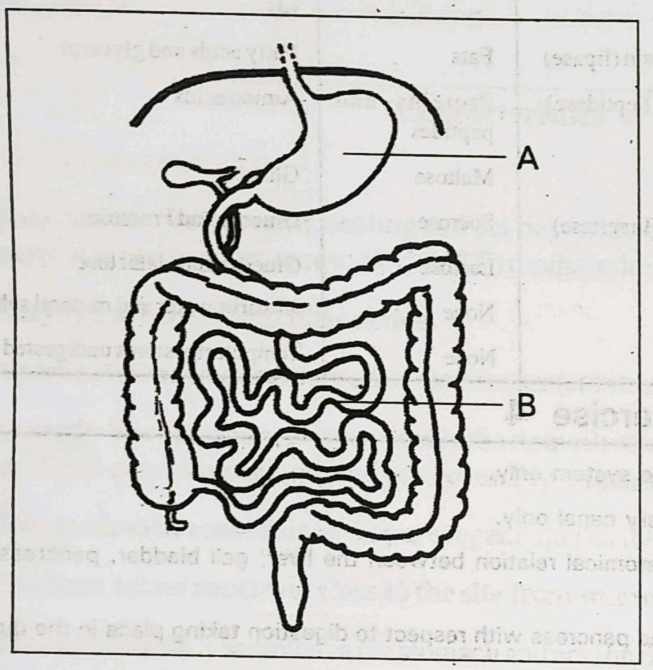
(iii) Which digestive enzyme is represented?

(iv) Name the substance on which the enzyme acts.

(v) State the function of this enzyme.

8. a. Copy the diagram given below and add in the figure:

(i) liver (ii) pancreas (iii) three sphincter muscles



b. List three functions of the liver directly concerned with the process of digestion/nutrition.

c. Name the parts (and label in fig.) that produce:

(i) Pepsin (ii) Trypsin (iii) Ptyalin

(iv) Maltase (v) Absorbs water

(vi) Stores undigested food/wastes temporarily

d. In which part of the gut would you find the villus?

e. State three significant characteristics of the villi, giving a reason for each.

f. Which part of the villus:

(i) Absorbs amino acids and glucose from food?

(ii) Absorbs fatty acids and glycerol from food?

g. Mention three differences between the chemical nature of food contained in part [A] and part [B].

9. a. What are enzymes?

b. Mention three characteristics of enzymes.

c. Mention three general uses of enzymes.

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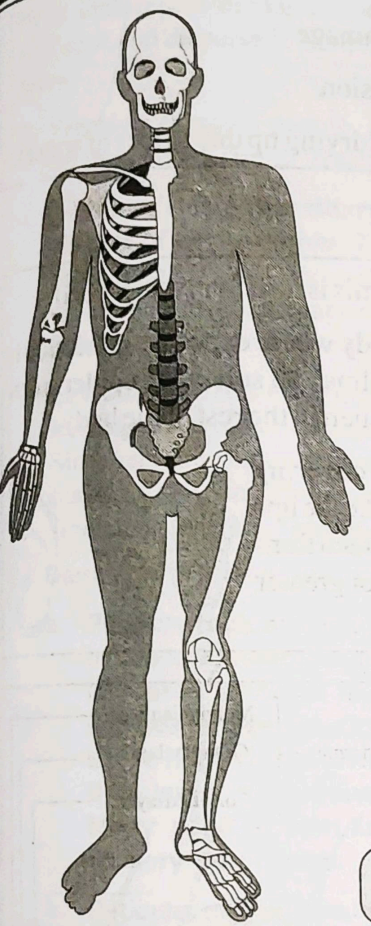
12
The Skin



Introduction

The internal body environment is largely fluid. All the inner cells are bathed in tissue fluid and most of the body substance is infiltered by fluid-containing blood and lymph vessels. The body therefore needs a waterproof outer covering to prevent the loss of this fluid. This protection is provided by the skin.

The skin is the largest of all body organs. It is an uninterrupted layer of tissue forming an impervious cover over the entire surface of the body. It forms the water-proof supple covering that gives body a proper shape.

The skin, however, is much more than a simple sealant. It is also one of the five **sense organs.** It enables us to perceive our environment by **touch.** Touch is a composite sense since, through it, we can perceive temperature, vibration, pressure, pin prick and pain. The other sense organs, which have been discussed in chapter 11, are the eye, ear, nose and the tongue. The skin also serves as an organ of excretion.

The Integumentary System

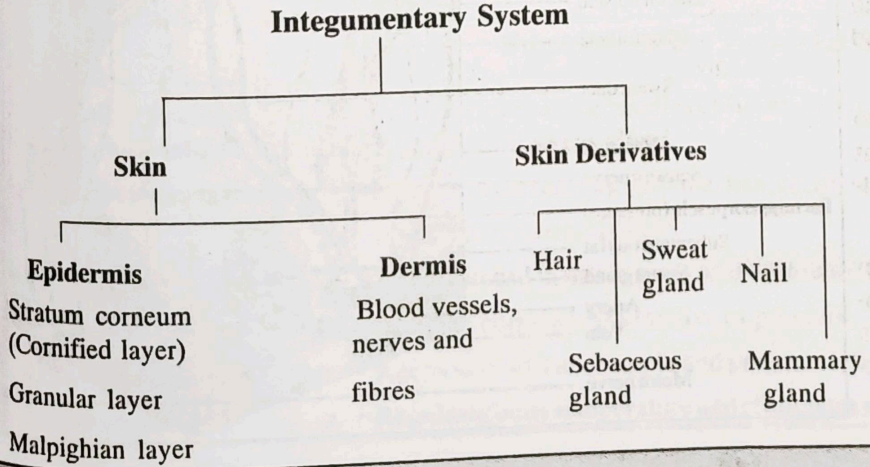
The skin is an organ because it consists of tissues structurally joined together to perform a specific function. The skin, together with its derivatives like the **hair, nails, glands** and several specialised **receptors,** constitute the **Integumentary System.**

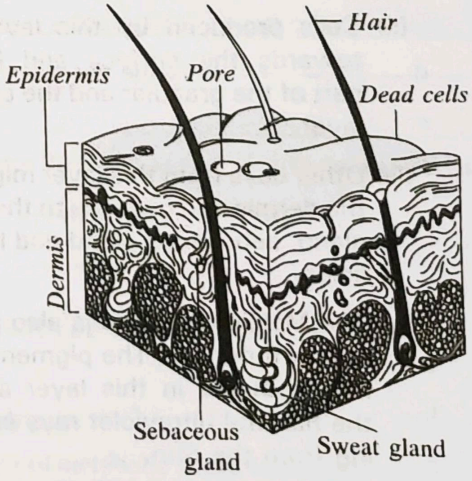
Dermatology: *It is the branch of science that deals with the diagnosis and treatment of skin disorders.*

Parts of the Integumentary System

Skin visible to the naked eye is nothing but dead and dying cells in several layers. Below this layer are the three chief functional layers of the skin.

The mammalian integumentary system can be divided as shown:





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Parts of the Skin

1. **Epidermis:** The epidermis is the outermost layer of the skin composed of thin stratified squamous epithelium. The epidermis lacks blood vessels.

Main Regions of the Epidermis

a. Stratum corneum or the cornified layer

The outermost layer or the epidermis consists of 25 to 30 rows of flat dead cells completely filled with **keratin**.

Keratin is a water proofing protein formed in the layer below the cornified layer and pushed up to the surface to replace the cornified layer which is continuously being shed. Keratin is also found in **nails, hair, horns** and **hoofs.**

The entire process by which a cell forms in the basal layers, rises to the surface, becomes keratinized and is shed, takes about two weeks.

b. Stratum Granulosum or the granular layer

This layer consists of three to five rows of flattened cells which lie below the cornified layer.

(i) These are concerned with the formation of keratin.

(ii) The nuclei of these cells are in various stages of disintegration and as such incapable of carrying out vital metabolic functions.

This layer gives way to the outermost cornified layer.

c. Stratum germinativum or the Malpighian layer

The deepest layer of the epidermis consists of a single layer of columnar cells.

(i) These are living cells capable of continued cell division.

(ii) Cells produced by this layer push towards the surface and become part of the granular and the cornified layer.

(iii) Other cells from this layer migrate to the dermis and give rise to the sweat gland, sebaceous gland and hair follicles.

(iv) The Malpighian layer is also **protective** in function. The pigment **melanin** produced in this layer absorbs the harmful ultraviolet rays emanating from the Sun.

Functions of the Cornified layer

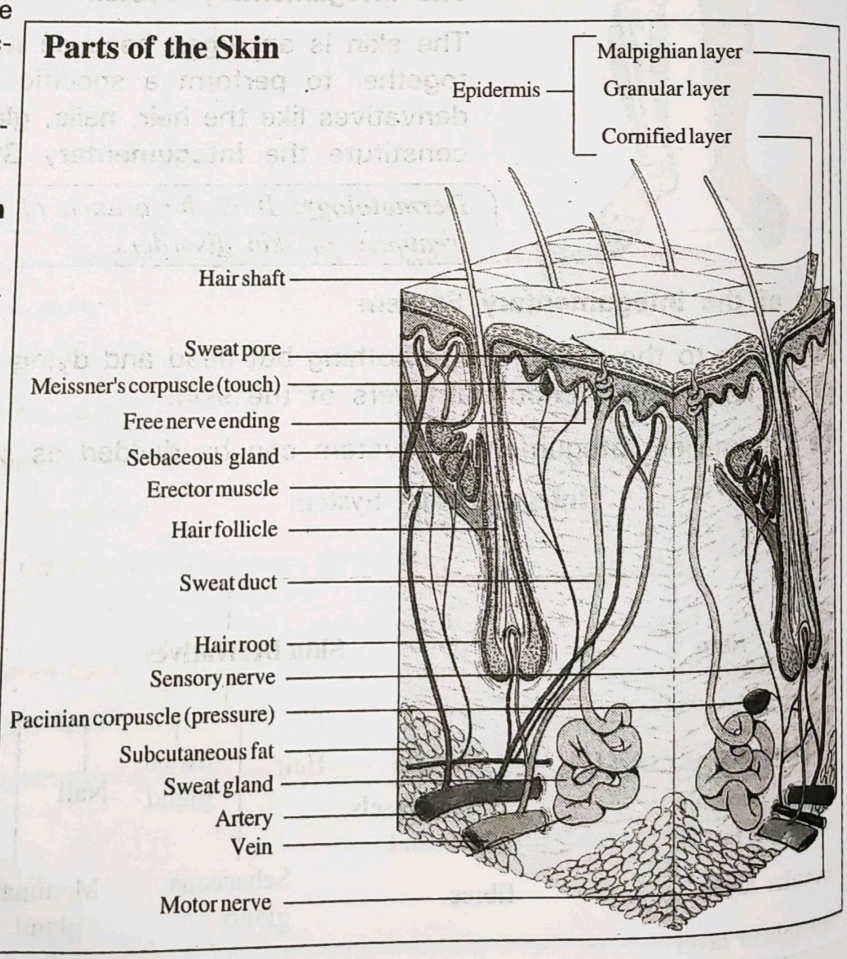
The cornified layer is tough and protects the underlying tissues from

1. Mechanical damage
2. Bacterial invasion
3. Dehydration (drying up due to loss of water).

Note: The epidermis is not evenly thickened.

1. Parts of the body where exposure to friction is maximum (palms and soles) the epidermis is much thicker than in the rest of the body.
2. The epidermis covering delicate parts like the lips and cheeks is much thinner, allowing for greater sensitivity.

Parts of the Skin



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(v) This layer also determines skin colour. **Melanin** is responsible for skin colour. (Another pigment called **carotene** is found in the stratum corneum and fatty areas of the dermis in people of Asian origin. Carotene and melanin together account for the yellowish hue of their skin.)

Note: Differences in skin colour is due to the amount of melanin produced and dispersed. Some common conditions are discussed below:

1. **Freckles:** In some people, melanin tends to form in spotted patches, giving rise to **'freckles'.**
2. **Albinism:** This is a **hereditary disease** characterised by **complete absence of pigmentation.** The skin of the individual (albino) appears pinkish due to the underlying blood vessels, while the hair, eyebrows and eyelashes appear golden. Being a hereditary disease, albino parents bear albino offsprings.
3. **Leucoderma:** This is a condition in which **skin pigmentation is lost in patches** of various sizes from different parts of the body. Since very little is known about its cause and cure, this otherwise harmless skin disorder is greatly feared by most people as a forerunner to leprosy or skin cancer.

2. **Dermis:** The dermis composed of the following:

a. **Papillary region:** The upper region of the dermis consists of loose **connective tissue** and has its surface greatly increased by small finger-like projections called **dermal papillae.** These structures project into the epidermis and cause ridges in the overlying epidermis. It is these ridges that leave **fingerprints** on objects that are handled. Many papillae contain loops of **blood capillaries** and **sensory corpuscles.**

b. **Reticular region:** The remaining part of the dermis is called the reticular region. Varying thickness of the reticular region partly contribute to the differences in the thickness of the skin. It is attached to the underlying organs such as bone and muscle by the **subcutaneous layer.** The **subcutaneous layer** also contains nerve endings called the **Pacinian corpuscle** that are **sensitive to pressure.**

Function of Malpighian Layer

1. **Divides to produce cells which**
   a. Replace the worn-out cells of the outer epidermis.
   b. Form skin derivatives like sweat gland and oil gland, hair follicle, etc.
2. **Produces the pigment melanin which**
   a. Gives colour to the skin.
   b. Protects the body against the harmful effects of ultraviolet rays.

Function of the Papillary Region

1. The connective tissue contains collagen and elastic fibres that make the dermis tough and flexible.
2. The blood capillaries provide nourishment to the skin.
3. Sensory corpuscles (Meissner's corpuscle) and nerve endings are sensitive to touch.
4. Epidermal ridges increase friction for better grasping ability.

Note: The subcutaneous layer is not a part of the skin but lies below the dermis. Since it is closely associated with the skin, its function is discussed here.

Function of the Reticular Region

The main reticular region is packed with interlacing bundles of fibres. Spaces between the fibres are occupied by **adipose tissue, nerves, hair follicle, ducts of oil gland,** and **sweat gland.**

1. **Subcutaneous tissue**: a. It protects the body against mechanical injuries.
   b. It helps to retain body heat.
   c. The fat stored in this layer is broken down (if required by the body) to provide energy.
2. **Sensory Corpuscles** : Pacinian corpuscle is sensitive to pressure.
3. **Sebaceous gland** : Keeps skin soft and supple and prevents it from drying up.
4. **Sweat gland** : Regulates body temperature and eliminates about 1% of metabolic waste through sweat.

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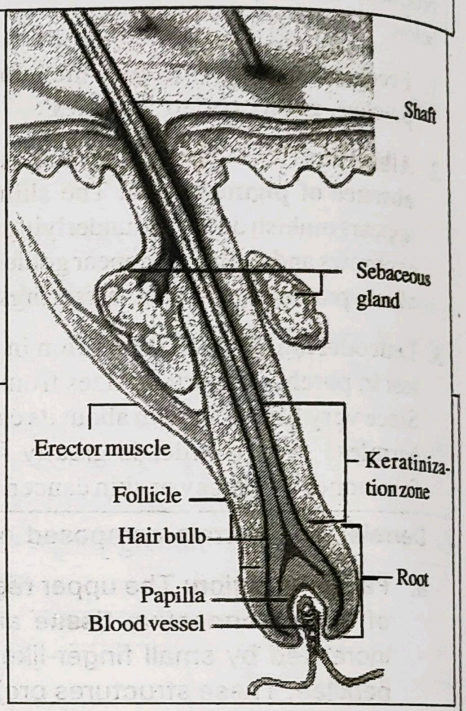
Skin Derivatives

The skin derivatives include the hair, sebaceous glands, sweat gland, nails and mammary glands.

1. **Hair:** Hair is a fine thread-like structure forming the exoskeleton of mammals. It has the following functions:
   a. **Provides Warmth:** In most animals (with thick furs) it serves to provide warmth by trapping an insulating layer of air.
   b. **Protection:** In some animals it provides protection as in the case of porcupines and hedgehogs. The quills of porcupine or hedgehog are special types of hair.
   c. **Sensory:** Hair growing on the cheeks of certain mammals like cats, dogs, rodents, etc. are sensory in function. Commonly known as whiskers, many nerves lie around these tactile hair and respond to touch and help the animal to feel their way around.

Note: In human beings hair is primarily **cosmetic** in function. Hair around the eyes and in the ear and nose prevent dust, insects and other substances from entering these parts. Hair is absent on the palms of the hand and soles of the feet.



Parts of the Hair

1. **Follicle:** The part of the hair extending below the skin surface and forming a baglike structure is called hair follicle. Around each hair follicle are nerve endings that are sensitive to touch. They respond if a hair shaft is moved.
2. **Bulb:** The root of the hair, i.e., the lowest part of the hair enlarges into a soft structure called the hair bulb. **The bulb is the only living tissue of the hair.** The cells of the bulb divide rapidly and add to the growth of the hair. Hair cells above the bulb are keratinized, hence dead.
3. **Papilla:** It is a structure projecting into the hair bulb at the base of the follicle. It is supplied with blood vessels to nourish the rapidly growing cells of the bulb.
4. **Shaft:** The part of the hair above the region where keratinization has occurred is called the shaft.

Sebaceous glands and **erector muscle** are also associated with hair.

The erector muscle is a smooth muscle extending from the dermis of the skin to the side of the hair follicle. In its normal position, the hair is arranged at an angle to the surface of the skin. Under conditions of cold or stress (e.g. fright) these muscles contract and pull the hairs into a vertical position resulting in what is commonly referred to as **"goose flesh"** or **"goose bumps"**.

2. **Sebaceous glands:** The sebaceous glands lie in the dermis and open into the neck of hair follicles. These glands secrete an oily substance called **sebum** which is a mixture of fats, cholesterol, proteins and inorganic salts. Sebum helps keep the skin smooth and supple and prevents it from drying up.

Function of Sebum

1. It helps to keep the hair from drying and becoming brittle.
2. Keeps the skin soft, pliable and waterproof.
3. Forms a protective film that prevents excessive evaporation of water from the skin.

Common problems associated with sebaceous gland

1. **Acne:** It is an inflammation of the sebaceous glands and usually occurs at puberty under the influence of certain hormones.
2. **Blackhead:** Sometimes the sebaceous glands of the face become enlarged due to accumulated sebum. Melanin and oxidized oil give it a black colour, hence the name **blackhead**.
3. **Pimples:** The sebum being nutritive to certain bacteria, often gets infected and results in the formation of **boils** and **pimples**.

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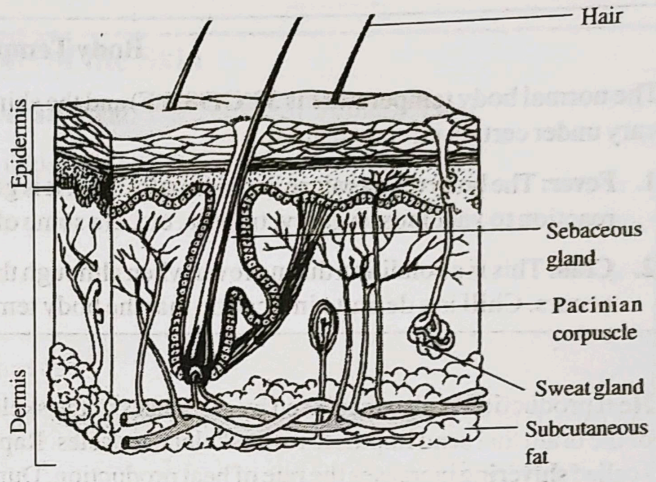
3. **Sweat glands:** The sweat gland is a simple, coiled, tubular gland distributed throughout the dermis except in certain regions such as the margin of the lips, nail bed, genitals and ear drum. They are most numerous in the skin of the soles and of the palm.

a. **The secretory part** of the gland, which occurs as a coiled tube, is located in the subcutaneous region of the dermis.

b. **The excretory part** of the gland, known as the **sweat duct** projects upwards through the dermis and epidermis and terminates on the skin surface as an opening called the **sweat pore.**



Composition of Sweat

Perspiration or **sweat** is a watery secretion produced by the sweat gland. It consists mainly of water and salt (NaCl) and minute quantities of metabolic wastes such as urea, uric acid, ammonia etc. It thus helps to eliminate wastes. Sweat is odourless until it has been broken down by bacteria on the skin surface. After decomposition it acquires a generally unpleasant odour. The evaporation of water from the sweat removes large quantities of heat from the body surface and cools the body.

Mechanisms of Heat Loss

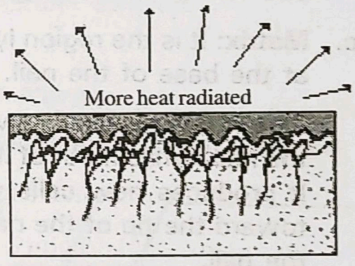
1. **Skin:** It accounts for nearly **85%** of the heat lost by the body. Heat loss is by conduction, convection, radiation and evaporation of water (sweat).
2. **Exhaled air from lungs:** The vaporisation of moisture (water) from the lungs takes up heat from the body and hence cools the body.
3. **Intake of cold food and beverages:** This also results in heat loss from the body.
4. **Removal of urine and faeces :** These substances are removed at body temperature.

Skin and Temperature Control

Humans are **warm blooded**, i.e., they maintain a constant body temperature. This is achieved by a group of reflex responses that are controlled by a region in the brain called the **hypothalamus**. Neurons in the anterior portion of the hypothalamus receive information about the external temperature from receptors in the skin and mucous membranes.

a. Vasodilation

1. When outside temperatures are high and the blood temperature increases, nerve impulses from the heat-losing centre of the hypothalamus stimulate nerves that cause the peripheral blood vessels of the skin to dilate.
2. Thus, blood flow to the skin is increased.
3. As a result, the sweat glands extract more water and salts from the blood and sweat production is increased.
4. Evaporation of water from the sweat causes cooling. This lowers and returns the body temperature to normal.

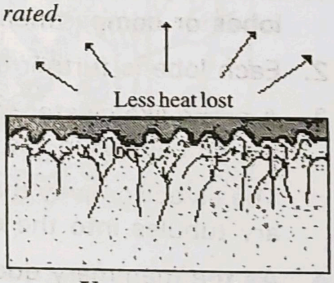


Vasodilation

Blood vessels are dilated. Blood flow to skin increased. More sweat produced and evaporated.

b. Vasoconstriction

1. When outside temperatures are low and the blood temperature falls below normal, nerve impulses from the heat-promoting centre in the hypothalamus stimulate nerves that cause the peripheral blood vessels of the skin to constrict.
2. As a result the flow of blood to the skin decreases.
3. The sweat glands extract less water and salts from the blood. Thus less sweat is produced.
4. Heat loss is reduced and the internal body temperature is raised.



Vasoconstriction

Blood vessels constrict. Blood flow to skin decreased. Less sweat produced, heat loss reduced and internal body temperature raised.

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Body Temperature Abnormalities

The normal body temperature is **37°C (98.4°F)** and the skin plays a vital role in maintaining it. However, the body temperature can vary under certain circumstances.

1. **Fever:** The body temperature is abnormally high. It is generally caused due to bacterial or viral infection. Heart attacks, tumours, reaction to vaccines, surgery, trauma, etc. are some of the other causes of fever.
2. **Chill:** This is a condition during fever when although the body temperature is above normal, the skin remains cold and **shivering** occurs. Chill is a definite indication that the body temperature is rising.

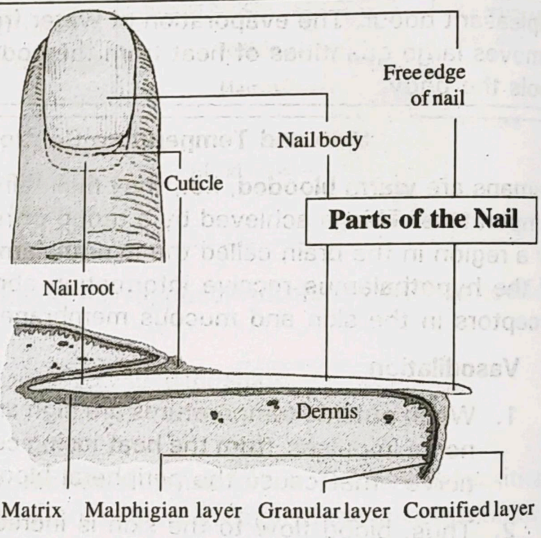
Shivering

Heat production is also increased by responses of the skeletal muscles. Stimulation of the heat-promoting centre stimulates a part of the brain that send impulses to the skeletal muscles. Rapid contraction and relaxation of the muscles occurs. This repetition cycle - called **shivering** increases the rate of heat production. During maximal shivering, body heat production can rise to about **four times the normal rate** in just a few minutes.

3. **Heat cramps:** This occurs as a result of profuse sweating that removes water and salt (NaCl) from the body. The loss of body salts causes painful contraction of muscles called heat cramps. The condition improves with the intake of salted liquids.
4. **Heat stroke** (Sun stroke)**:** When the outside temperature and relative humidity are high, it becomes very difficult for the body to lose heat either by radiation or evaporation. Perspiration is greatly reduced and the body temperature rises sharply - **sometimes as high as 43°C.** Brain cells are permanently damaged at such high temperatures.

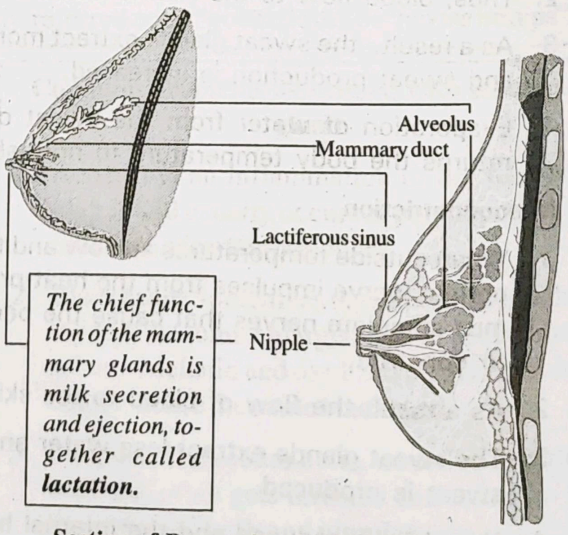
4. **Nails:** The nail is composed of mainly the plate, bed and matrix.
   a. **Plate (Nail body):** It is the hard outer part of the nail made up of dead, keratinized cells.
   b. **Bed (Nail root):** The bed lies below the plate. Both the bed and the plate originate from the matrix.
   c. **Matrix:** It is the region lying just below the skin surface, at the base of the nail.

   Part of it is visible as a whitish half-moon at the base of the nail, while most of it remains covered with the skin. It produces new cells which push out the older ones toward the tip of the nail. This results in the growth of the nail.



5. **Mammary glands:** These glands are modified sweat glands. With the onset of puberty, the female breast begins to develop.
   1. Internally, each mammary gland consists of 15 to 20 **lobes** or compartments separated by adipose tissue.
   2. Each lobe is further divided into **lobules.**
   3. A grape-like cluster of milk-secreting cells called **alveoli** are embedded in the lobules.

      The alveoli convey the milk, through a series of secondary tubules into the mammary duct.
   4. As the mammary duct approaches the nipple, it forms sinuses where the milk may be stored. These sinuses continue as the lactiferous ducts which terminate in the nipple.
   5. The circular pigmented region around the nipple is called the **areola.** It appears rough because it contains certain modified sebaceous glands.



*The chief function of the mammary glands is milk secretion and ejection, together called **lactation.***

Section of Breast showing Mammary Glands

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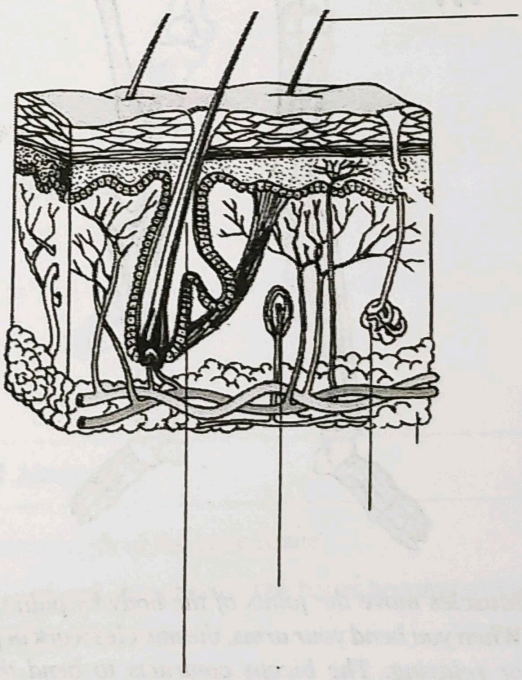
A Summary of the Functions of the Skin

The skin is complex in structure, performing several functions vital to our survival.

1. **Protection :** The skin completely envelops the body and protects the underlying tissues from:
   a. Mechanical injury
   b. Bacterial invasion
   c. Dehydration (desiccation or drying up due to loss of water)
   d. Harmful effects of the ultra violet radiations (emanating from the sun)
2. **Sensory function** (Reception of stimuli)**:** Nerve endings and sensory corpuscles present in the skin are sensitive to stimuli of temperature, touch, pain and pressure.
3. **Regulation of body temperature:** In response to high environmental temperature or strenuous exercises, glands (sweat) in the skin produce perspiration which helps to maintain body temperature.
4. **Excretion:** The skin removes excess water, inorganic salts and organic metabolic wastes through sweat.
5. **Storage of Food and Insulation:** Excess fat is stored in the subcutaneous layer beneath the skin. This fat layer also keeps the body warm (provides insulation against cold).
6. **Synthesis of Vitamin D:** The skin has the ability to synthesize small quantities of vitamin D on exposure to the Sun.

Exercise

1. State the location and important functions of the following
   a. Malpighian layer
   b. Sebaceous gland
   c. Sweat gland
   d. Hair
   e. Subcutaneous fat layer
   f. Stratum corneum
2. **State two differences between**
   a. Vasodilation and Vasoconstriction
   b. Leucoderma and Albinism
   c. Sweat and Sebum
   d. Meissner's corpuscle and Pacinian corpuscle
   e. Heat cramp and Heat stroke
3. Label the parts indicated by the guidelines.



4. **Fill in the blanks:**
   (i) _____ is a branch of science dealing with the study of skin disorders.
   (ii) Blood vessels are absent in the _____ of the skin.
   (iii) _____ is the only living tissue of the hair.
   (iv) Nails are composed of three main parts viz. _____, _____ and _____ .
   (v) The temperature regulating centre is a region in the brain called the _____ .
   (vi) The normal body temperature in humans is _____ .
   (vii) The various ways by which the body loses heat are through the _____, _____, _____ and _____ .
   (viii) Goose flesh is caused due to the contraction of _____.
   (ix) Mammary glands are modified _____ glands.
   (x) The secretion and ejection of milk from the milk ducts is called _____ .

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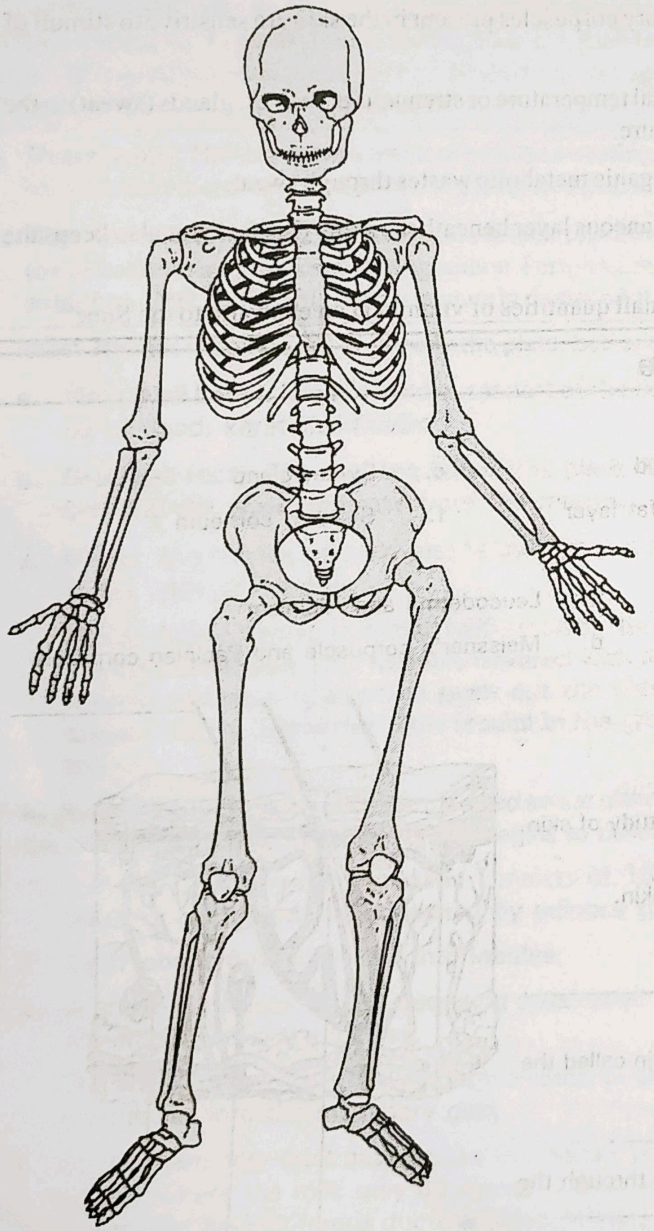
13
The Skeletal System

Introduction

The skeleton is among the busiest and the most durable of all living organs of the body. Human bones have been found that are nearly a million years old.

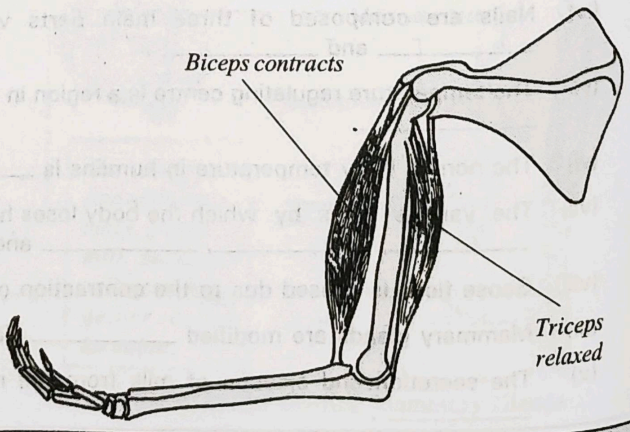


Apart from forming the supporting framework of the body, the bones are manufacturing units for **red blood cells** (which transports oxygen to the various tissues), **white blood cells** (which fight infection), and **platelets** (which are essential for clotting of blood).

Bones also act as the body's storehouse for reserve nourishment. The marrow of the bone stores fats, proteins, calcium and phosphorus. By an intricate self-regulating system the calcium ingested through milk and eggs is deposited in the bones while the calcium depsotied earlier is withdrawn for the current use of the body.

The skeleton protects the delicate organs of the body. The **cranium** protects the brain, the **ribs** enclose the heart and lungs while the spinal cord is protected by the **vertebrae**. As a supporting structure, bone construction can be compared to reinforced concrete. On a weight-to-weight basis, bones are stronger than steel. The leg bones which support the entire body weight are light in keeping with the engineering principle that a hollow column is stronger than a solid one of the same weight.

The separate unit of the skeletal framework is the **bone. Bone and muscles work together to bring about movement** Bones are connected to each other by ligaments. Skeletal muscles produce movements by exerting force on tendons, which in turn pull on bones or other structures, such as the skin. Most movements are coordinated by several skeletal muscles acting in groups and these are generally arranged in opposing pairs at joints.



Muscles move the joints of the body by pulling- they never push. When you bend your arms, the muscles work in pairs, either pulling or relaxing. The biceps contracts to bend the arm, the triceps contracts to straighten it.

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Functions of the Skeletal System

The skeletal system is made up of bones of the **limbs** (hands and legs), **skull, ribs** (chest) and the **vertebra** (back bone). The largest bone in the body is the **femur** and the smallest is the bone in the ear, called **stirrup.**

Function of the Skeletal System

The skeletal system performs the following basic functions

1. **Support:**

   It provides a framework for the body and supports soft tissues.

   * **Skull** protects the **brain.**
   * **Ribs** protect the **heart** and **lungs.**
   * **Vertebrae** protect the **spinal cord.**

2. **Protection:**

   Protects delicate organs from injury.

3. **Attachment for muscles:**

   It provides a surface for the attachment of muscles.

4. **Movement:**

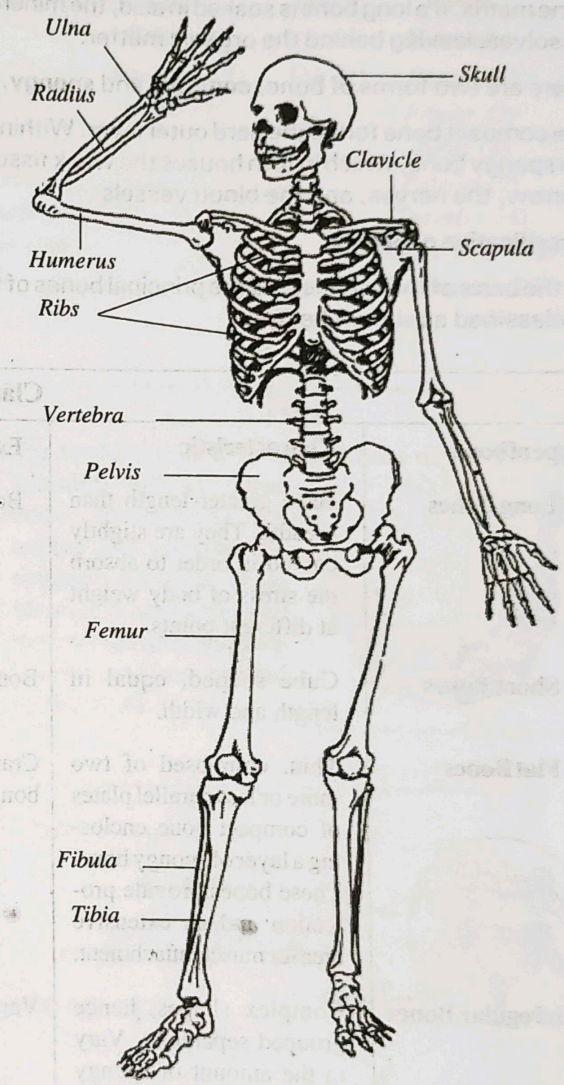
   Bones serve as levers to which muscles are attached. When muscles contract, bones acting as levers and joints acting as fulcrum produce movement.

5. **Storage of**

   a. Minerals: Principal stored minerals are calcium and phosphorus.

   b. Energy: Yellow bone marrow stores lipids which is an important source of energy.

   c. Blood cells: Red marrow produces red blood cells, white blood cells and platelets. The red marrow also stores immature blood cells and fats.



Male and Female Skeleton

Male bones are generally larger and heavier than female bones. They have more prominent markings for muscle attachment. The female pelvis is wider and adapted for pregnancy and childbirth.

Principal disorders of the Skeletal System

1. **Osteoporosis :** Generally due to aging. Loss of calcium from bones decreases strength of the bone tissue.
2. **Rickets :** Vitamin D deficiency in children. Inability of the body to absorb calcium and phosphorus. The bones become soft and bend under body weight.
3. **Osteomalacia :** Demineralisation caused by Vitamin D deficiency in adults.

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Bones: The basic Unit of the Skeletal System

The separate unit of the skeletal framework is the **bone.** Bones are connected to each other by ligaments.

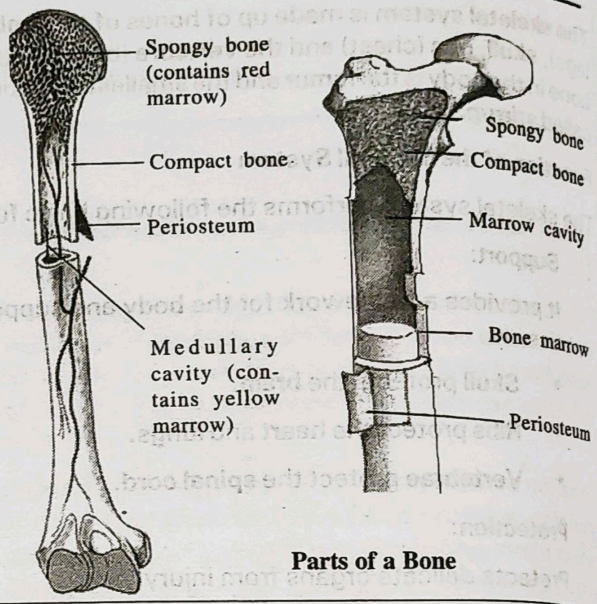
About two-thirds of the weight of bone tissue is mineral, made up of calcium, phosphate and carbonate. The rest is organic material consisting largely of fibrous protein **collagen.** When boiled in water, collagen yields **gelatin.** Together, the mineral and collagen, form the bone matrix. If a long bone is soaked in acid, the mineral component dissolves, leaving behind the organic matter.

There are two forms of bone, **compact** and **spongy.**

The compact bone forms the hard outer layer. Within this layer lies the spongy bone, which in turn houses the weak tissue of the bone marrow, the nerves, and the blood vessels.

Classification of Bones

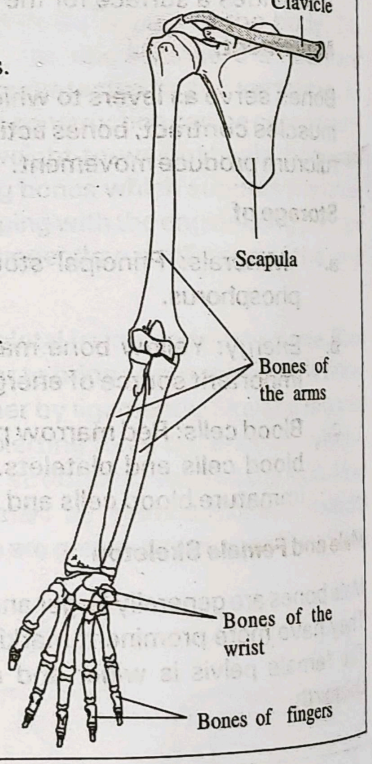
On the basis of their shapes, all the principal bones of the body may be classified as shown below



Parts of a Bone

Classification of Bones

Type of bone	Characteristic	Example
1. **Long Bones**	Have greater length than breadth. They are slightly curved in order to absorb the stress of body weight at different points.	Bones of the thigh, arms, fingers and toes.
2. **Short Bones**	Cube shaped, equal in length and width.	Bones of the wrist and ankles.
3. **Flat Bones**	Thin, composed of two more or less parallel plates of compact bone enclosing a layer of spongy bone. These bones provide protection and an extensive area for muscle attachment.	Cranial bones, sternum, scapula (shoulder bone), ribs.
4. **Irregular Bones**	Complex shapes, hence grouped separately. Vary in the amount of spongy and compact bone present.	Vertebrae, facial bones.



Role of Calcium

Calcium is necessary for the clotting of blood, beating of the heart, contraction of muscles, and the functioning of the nervous system.

If the calcium ingested through food is inadequate, than the body withdraws some of the calcium from the skeleton bank.

Children on a poor milkless diet have so much calcium taken away, that their bones become soft and crooked.

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Divisions of the Skeletal System

The adult human skeleton consists of 206 named bones. These are grouped in two principal divisions.

Skeletal System [206 bones : includes ear ossicles]

Axial [73 bones]

Skull	Vertebral Column	Thorax Girdle
Cranium (8)	*(26)*	*Sternum (1)*
Face (14)		*Ribs (24)*

Appendicular [126 bones]

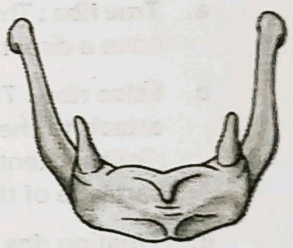
Pectoral	Upper Extremity	Pelvic	Lower Extremity
Clavicle (2)	*Humerus (2)*	*Hip (2)*	*Femur (2)*
Scapula (2)	*Ulna (2)*		*Fibula (2)*
Radius (2)			*Tibia (2)*
Carpals (16)			*Patella (2)*
Metacarpals (10)			*Tarsals (14)*
Phalanges (28)			*Metatarsals (10)*
			Phalanges (28)

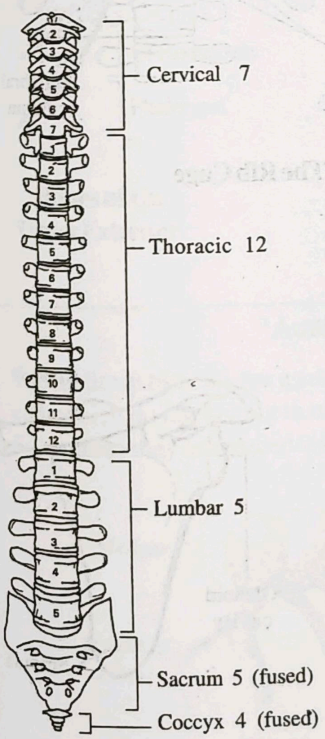
A. The Axial Skeleton

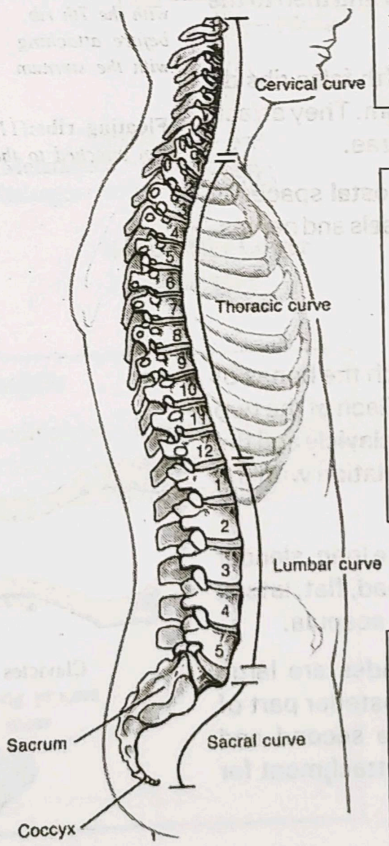
1. **Skull :** The skull consists of the cranium and the face. The cranial bones are 8 in number while the facial bones are 14. The skull is thus composed of 22 bones. Sutures are immovable joints between bones of the skull.
2. **Vertebral column:** The vertebral column, sternum and ribs constitute the skeleton of the trunk. The vertebral column, when viewed from the side shows four curves. The curves lend flexibility to the backbone and absorb the shock of impact. Therefore, one is able to carry heavy loads on the head.

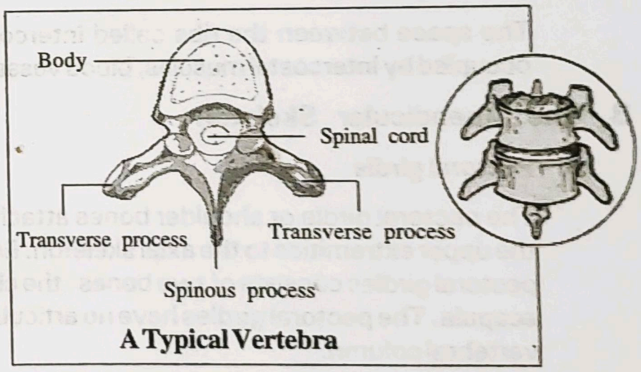
Note

The hyoid bone is a 'U' shaped bone which does not articulate with any other bone. It supports the tongue and provides attachment for some of its muscles. Some of the neck muscles and muscles of the pharynx are also supported by the hyoid.









A Typical Vertebra

Significance of a Curved Vertebral Column

1. It helps maintain balance in an upright position.
2. The curves absorb shock from walking.
3. It protects the column from fracture.

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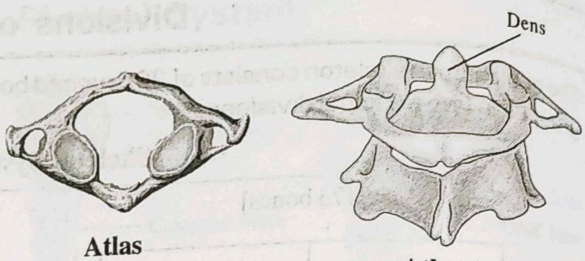
A typical vertebra consists of a body, vertebral arch and seven processes. The first two cervical vertebrae i.e., the **atlas** and the **axis**, differ from the other vertebrae.

a. **Atlas:** It is a ring of bones and lacks the body and spinous processes. It supports the head (skull).

b. **Axis:** It has a body and a peg-like process (called dens) which projects through the ring of the atlas. The dens makes a pivot on which the atlas and the head can rotate, allowing a side-to-side rotation of the head.



Atlas

Atlas-Axis

3. Thorax

The thoracic skeleton consists of the sternum, ribs and the thoracic vertebrae. The thoracic cage protects vital organs in the chest and upper abdomen.

Sternum (Breastbone) : It is a flat narrow bone located in the median line of the anterior thoracic wall. It provides attachment for some abdominal muscles. The body of the sternum articulates directly or indirectly with the second through tenth ribs.

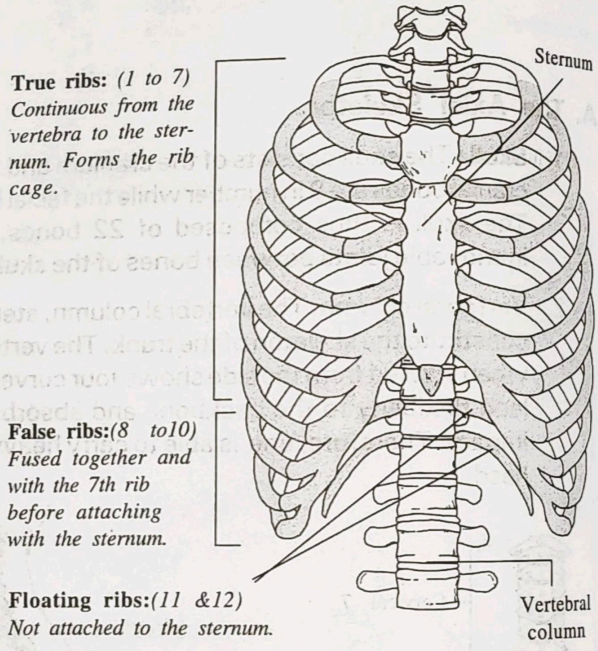
Ribs : Twelve pairs of ribs make up the sides of the thoracic cavity.

a. **True ribs :** These are the first seven pairs of ribs which have a direct anterior attachment to the sternum.

b. **False ribs :** The next five pairs of ribs do not directly attach to the sternum. The cartilages of the eighth, ninth and tenth ribs attach to each other and then to the cartilage of the seventh rib.

c. **Floating ribs :** The eleventh and twelfth false ribs do not attach even indirectly to the sternum. They attach only posteriorly to the thoracic vertebrae.

The space between the ribs called **intercostal** spaces is occupied by **intercostal** muscles, blood vessels and nerves.



The Rib Cage

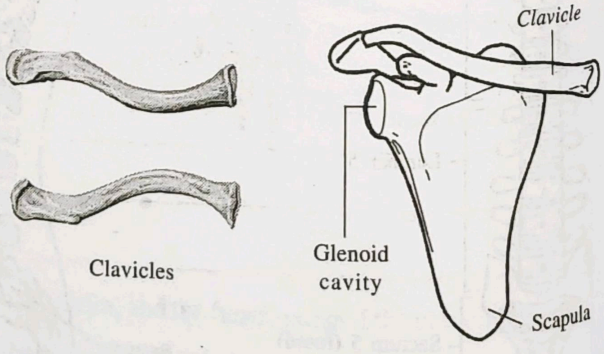
B. The Apendicular Skeleton

1. Pectoral girdle

The pectoral girdle or shoulder bones attach the bones of the upper extremities to the axial skeleton. Each of the two pectoral girdles consists of two bones , the **clavicle** and the **scapula.** The pectoral girdles have no articulation with the vertebral column.

a. **Clavicles** (Collar bone) : The clavicles are long, slender bones with a double curvature. The broad, flat, lateral end of the clavicle articulates with the scapula.

b. **Scapula:** The scapula or shoulder blades are large triangular, flat bones situated in the posterior part of the thorax between the levels of the second and seventh ribs. It provides a surface of attachment for shoulder joints.



Clavicles

The Pectoral Girdle

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2. **Upper extremity (arms)**

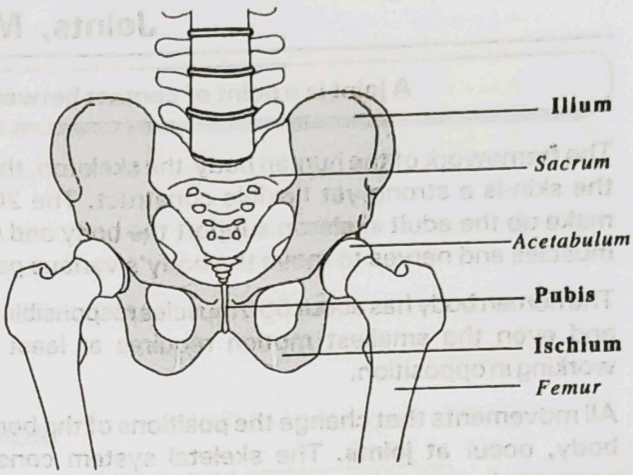
The bones of each upper extremity include the **humerus, ulna, radius, carpals, metacarpals** and **phalanges.**

3. **Pelvic girdle (hip)**

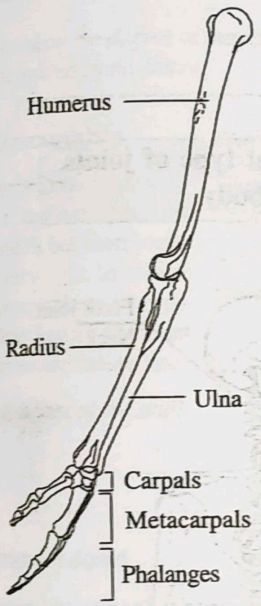
The pelvic girdle consists of two hip bones which attach the lower extremities to the trunk at the sacrum. Each hip bone has three fused components **ilium, pubis** and the **ischium.**

4. **Lower extremity (legs)**

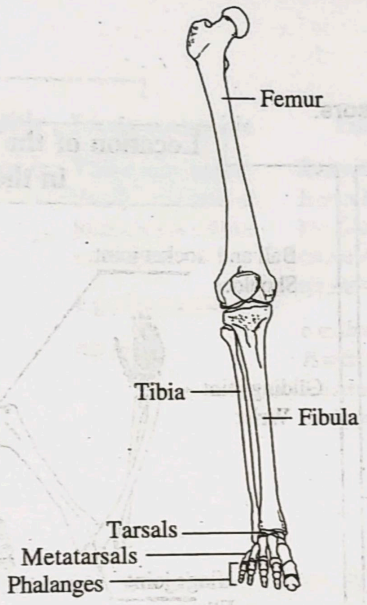
The bones of each lower extremity include the **femur, tibia, fibula, tarsals, metatarsals** and **phalanges.** The bones of the foot are arranged in two arches -- the longitudinal arch and the transverse arch, to provide support and leverage.



The Pelvic Girdle



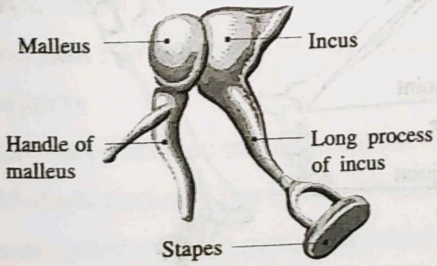
Bones of the Upper Extremity



Bones of the Lower Extremity

Auditory Ossicles

The auditory ossicles are a set of exceedingly small bones - 3 in each ear - which do not belong to either the axial or appendicular skeleton. Sometimes they are placed with the axial skeleton for convenience.



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Joints, Muscle and Movement

A joint is a point of contact between bones and cartilage, or between teeth and bones.

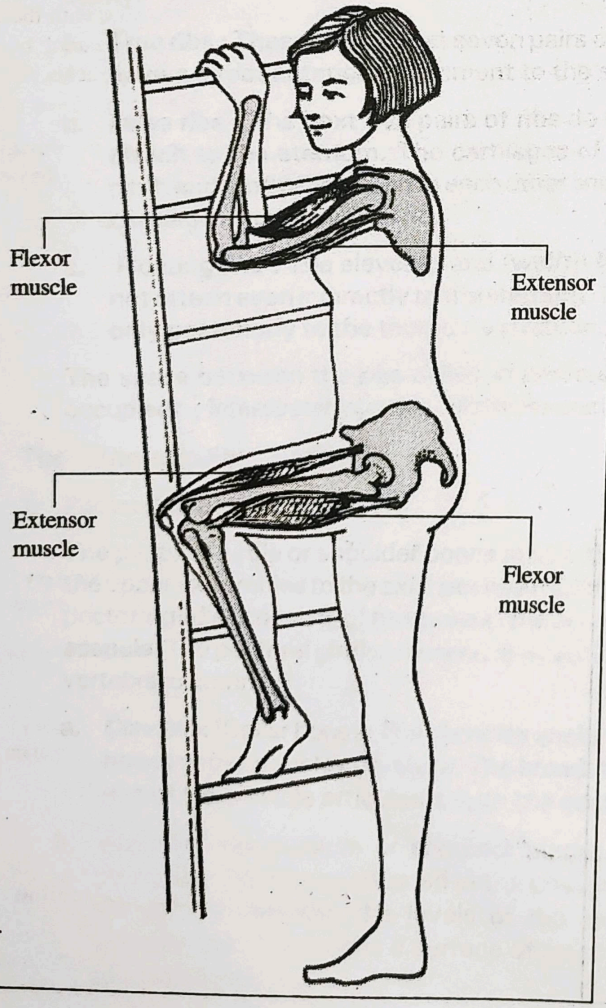
The framework of the human body-the skeleton, the muscles and the skin-is a strong yet flexible construct. The 206 bones that make up the adult skeleton support the body and work with the muscles and nerves to move the body's various parts.

The human body has about 650 muscles responsible for movement and even the smallest motion requires at least two muscles working in opposition.

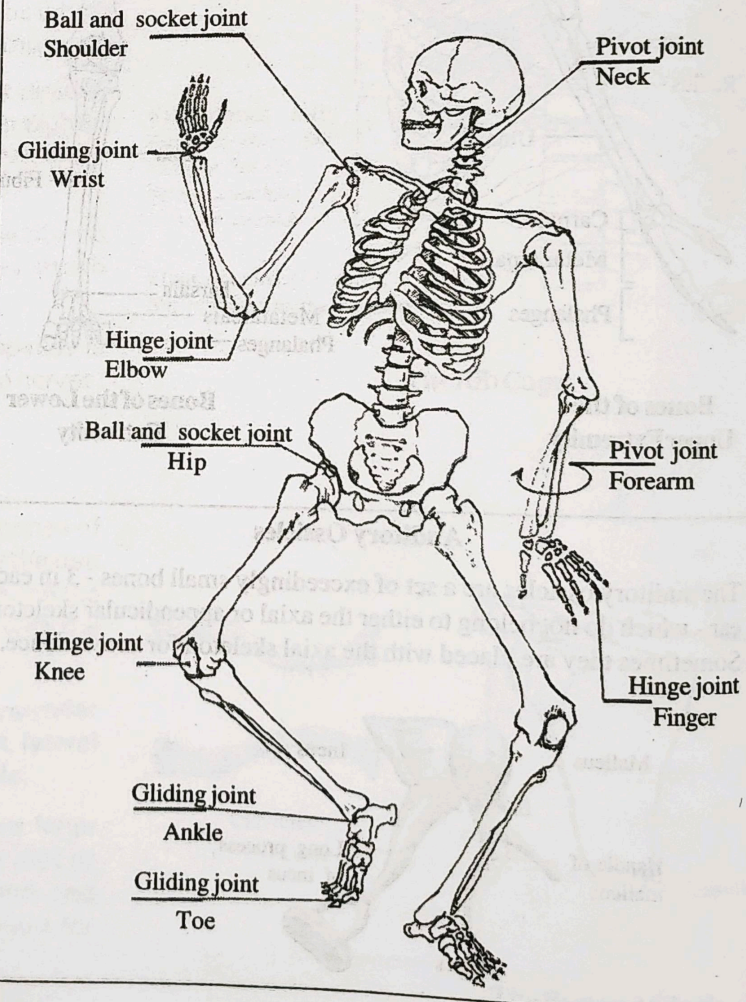
All movements that change the positions of the bony parts of the body, occur at **joints**. The skeletal system consists of many separate bones, most of which are held together at joints by flexible connective tissue. Joints are necessary since bones are too rigid to bend without causing damage.

* Muscles that bend a joint are called **flexors**.
* Muscles that straighten a joint are called **extensors**.

Main Muscle types



Location of the important type of joints in the human body



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Classification of Joints

Most joints are movable, and in these the joints are covered with a layer of cartilage. They slip over each other easily because the cartilage is smooth and lubricated with a special fluid. The whole joint is enclosed in a tough membrane.

Some joints, such as the plates which make up the top and sides of the skull do not move. These are called **fixed joints.**

Joints may be classified on the basis of their function or their structure.

The following chart outlines both the systems of classification.

Classification of Joints

Functional

(Based on the degree of movement permitted by the joint).

Immmovable

These joints do not allow any movement as their fit between bones is very tight. In case of sutures, there is complete fusion of bones across the suture line.

e.g. *bones of the skull.*

Partially moveable

These joints allow very slight movement.

e.g. *between bodies of vertebrae.*

Freely moveable

These are essentially synovial joints capable of free movement.

e.g. *elbow joint,*

hip joint.

Structural

(Based on the presence or absence of the synovial cavity and the kind of connective tissue that binds the bones together).

Fibrous

Synovial cavity absent. Bones held very closely by fibrous connective tissue. Allows little or no movement.

e.g. *bones of the skull. Roots of the teeth with sockets of the maxillae and mandible.*

Cartilagenous

Synovial cavity absent. Bones held together tightly by cartilage. Allows little or no movement

e.g., *joint between the first rib and the sternum. Between bodies of vertebrae.*

Synovial

Synovial cavity present. The cavity, together with the arrangement of bones and ligaments, allows free movement.

e.g. *elbow, shoulder, hip, neck, wrist joint.*

Synovial Joint

A joint in which there is a space between articulating bones is called a synovial joint. Synovial joints contain a synovial cavity, cartilage, synovial membrane and ligaments.

All synovial joints are freely movable.

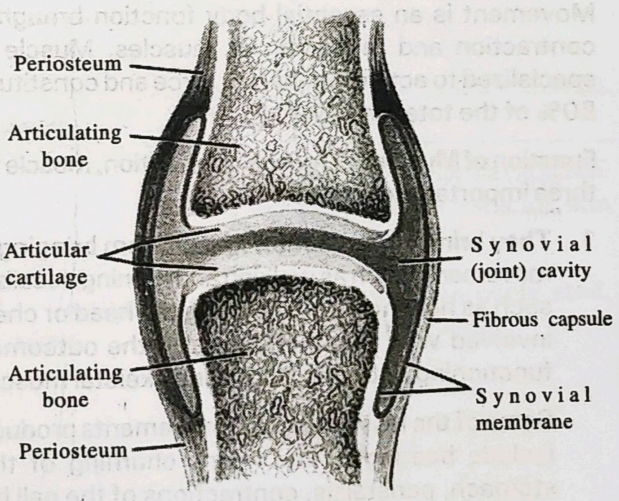
Types of **movement** at synovial joints include gliding movements, angular movements, rotation and special movements.

Types of **synovial joints** include gliding joint, hinge joint, pivot joint, ball-and-socket joint.

Knee Joint : The knee joint is the largest joint of the body. It is formed by three joints.

1. **Gliding joint :** Between the patella (knee cap) and femur.
2. **Hinge joints**
   a. Laterally between the tibia and femur.
   b. Medially between the tibia and femur.

The knee joint allows flexion, extension, medial and lateral rotation.



Generalised Synovial joint in frontal section

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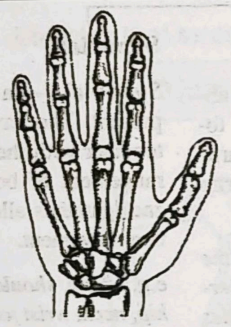
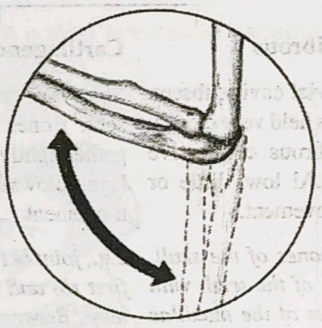
Types of Synovial Joints

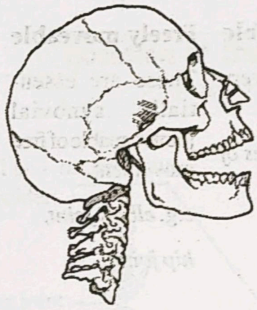
Type of Joint	Characteristic	Examples
1. Gliding joint	The articulating surfaces of bones are usually flat. Only side to side and back and forth movement permitted.	Joints between carpals, tarsals; strenum and clavicle; scapula and clavicle.
2. Hinge joint	The convex surface of one bone fits into the concave surface of another. Motion is similar to that of a hinge door comprising of flexion and extension.	Elbow, ankle, interphalangeal joints.
3. Pivot joint	A rounded, pointed or conical surface of one bone articulates within a ring formed partly by another bone and partly by a ligament.	Joint between atlas and axis allows rotation of head from side to side. Proximal ends of the radius and ulna.
4. Ball-and-socket joint	Primary movement permitted is rotation. This joint consists of a ball-like surface of one bone fitted into a cup-like depression of another bone. It allows movement in three planes of motion.	**Shoulder joint :** The head of the humerus is the ball which fits into the cup of the glenoid cavity. **Hip joint :** The head of the femur (ball) fits into the acetabulum (cup).



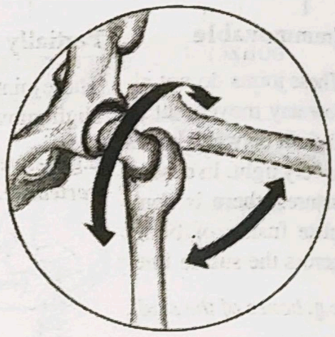
Gliding joint



Hinge joint



Pivot joint



Ball-and-socket joint

Muscles

Bones and joints are incapable of moving the body on their own. Movement is an essential body function brought about by the contraction and relaxation of muscles. Muscle tissue is higly specialized to actively generate force and constitutes about 40 to 50% of the total body weight.

Function of Muscles : Through contraction, muscle tissue performs three important functions

1. **They bring about motion :** Apart from bringing about obvious movements such as walking and running, localized movements such as holding a pen, nodding the head or chest movements involved with breathing are also the outcome of integrated functioning of bones, joints and skeletal muscles.

   Some of the less noticeable movements produced by muscles include beating of the heart, churning of the food in the stomach, peristalsis, contractions of the gall bladder and the urinary bladder.

2. **Help to maintain body posture :** The muscle tissue enables the body to maintain posture. The contraction of skeletal muscles holds the body in stationary positions such as standing and sitting.

Characteristics of Muscle

Muscle tissue show the following characteristics :

1. **Excitability :** The property of receiving and responding to stimuli.
2. **Contractility :** The ability to shorten and thicken (contract).
3. **Extensibility :** The ability to be stretched (extended).
4. **Elasticity :** The ability to return to original shape after contraction or extension.

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3. **Heat production :** Almost 85 % of all body heat is generated by muscle contractions. Hence muscles are important in maintaining normal body temperature. The immediate, direct source of energy for muscle contraction is ATP, adenosine-triphosphate which is derived from the complete breakdown of pyruvic acid to CO_2 and H_2O in the presence of oxygen (Kreb's cycle). Muscle fibres generate ATP continuously by the metabolism of fats and glycogen. Nerves convey impulses for muscular contraction, while blood provides nutrients and oxygen for contraction.

Muscle Tissue and Muscular System

The term **muscle tissue** refers to all contractile tissues of the body : the skeletal, cardiac and smooth muscle.

The **muscular system** refers only to the skeletal muscle tissue and connective tissues.

Oxygen Debt

During exercise, blood flow to muscles is increased in order to increase the available oxygen supply. However, if the muscular exertion is very great, oxygen cannot be supplied to muscle fibres fast enough and all the ATP required for further muscle contraction is not generated. At such times, ATP is generated in the absence of oxygen (**anaerobic-glycolysis**) during which most of the **pyruvic acid** is converted to **lactic acid**. Although 80% of the lactic acid diffuses from the skeletal muscles and is transported to the liver for conversion back to glucose or glycogen, some lactic acid accumulates in muscle tissue. Thus, when adequate oxygen is available, lactic acid is catabolized completely into carbon dioxide and water.

The additional oxygen that must be taken into the body after vigorous exercise to restore all systems to their normal states is called **oxygen debt**. The debt is paid back by laboured breathing that continues after exercise has stopped. Muscle glycogen is restored through diet, and may take several days, depending on the intensity of exercise.

Muscle Fatigue

The inability of a muscle to maintain its strength of contraction or tension is called ***muscle fatigue.***

It occurs when a skeletal muscle or a group of skeletal muscles is continuously stimulated for an extended period of time. As a result, the strength of contraction becomes progressively weaker until the muscle no longer responds. In short, the muscle is unable to produce sufficient energy to meet its needs.

Its cause may be due to insufficient oxygen, depletion of glycogen and/ or lactic acid build up.

Classification of Muscles

All muscle tissues are classified in the following way

1. Skeletal, striated, voluntary muscle tissue.
2. Cardiac, striated, involuntary muscle tissue.
3. Smooth, non-straited, involuntary muscle tissue.

The principal characteristics of muscle tissues are summarized below.

Characteristic	Skeletal muscle	Cardiac muscle	Smooth muscle
Location	Attached primarily to bones.	Heart	Walls of hollow viscera (stomach, intestines), blood vessels, iris, skin (erector muscle).
Microscopic appearance	Striated (presence of alternating light and dark bands, multi-nucleated, unbranched fibres.	Striated, uninuceated, branched fibres.	Non-striated, uninucle-ated, spindle-shaped fibres.
Nervous control	Vountary (i.e under the control of the conscious mind).	Involuntary	Involuntary
Speed of contraction	Rapid	Moderate	Slow
Capacity for division	None. Growth is due to enlargement of existing cells.	None	Limited

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Muscles and Movement

Skeletal muscles produce movements by exerting force on tendons, which in turn pull on bones or other structures, such as the skin. Most movements are coordinated by several skeletal muscles acting in groups and these are generally arranged in opposing pairs at joints.

A muscle that contracts to bring about a certain movement is called the **agonist** or the prime mover. Simultaneously with the contraction of this muscle another muscle called the **antagonist** relaxes to yield to the movement of the agonist.

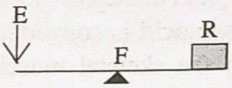
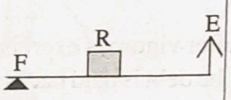
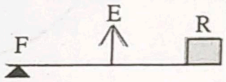
How Skeletal Muscles produce Movement

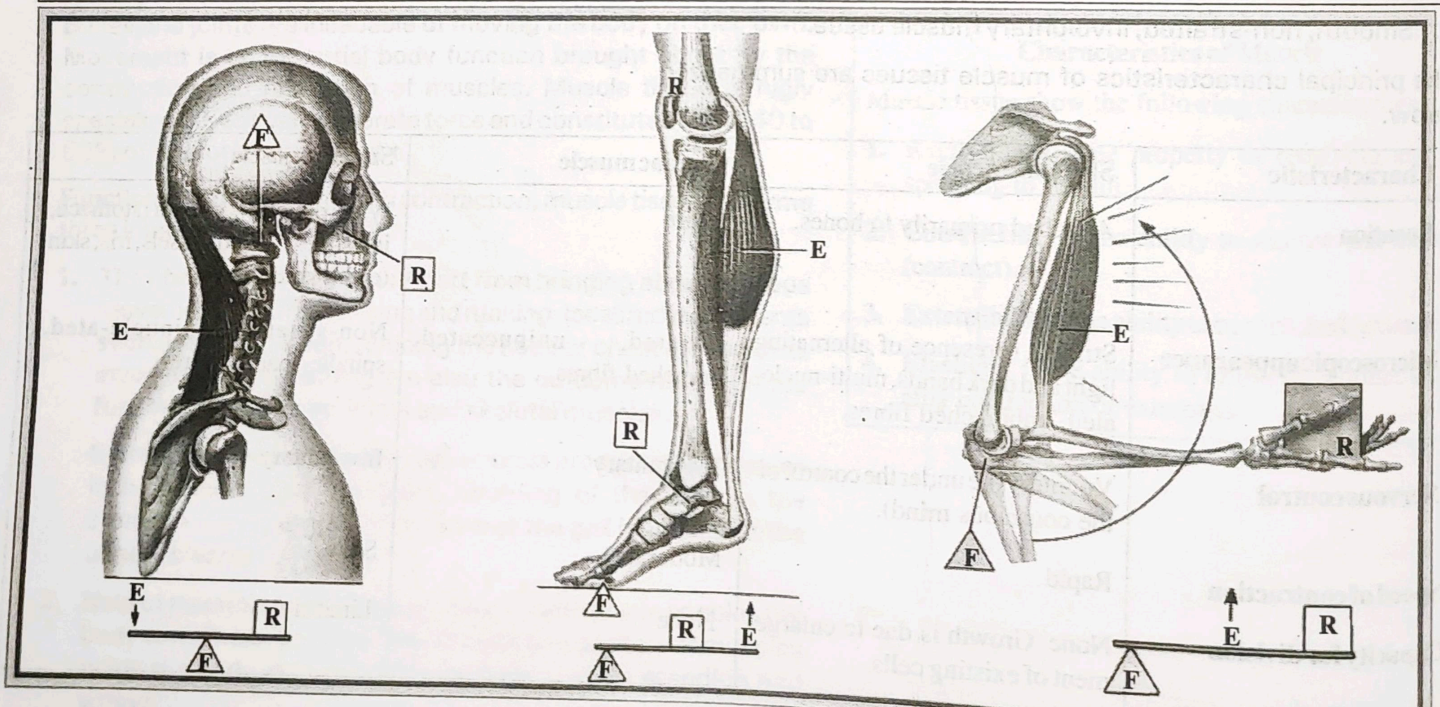
In producing a body movement, bones act as levers and joints act as fulcrums of these levers.

A **lever** may be described as a rigid rod that moves about a fixed point called a **fulcrum (F).**

A lever may be acted on at two different points by two different forces-the **resistance (R)** and the **effort (E).**

* Resistance is the load to be overcome.
* Effort is the force exerted to overcome the resistance.

Class of Lever	Example
Class I lever (EFR) (Fulcrum is between the effort and resistance) 	**Resistance:** Facial portion of the skull. **Fulcrum:** Joint between the atlas and the occipital bone. **Effort:** Contraction of back muscles.
Class - II lever (FRE) (Resistance is between the fulcrum and the effort) 	**Resistance:** The body. **Fulcrum:** Ball of the foot. **Effort:** Contraction of the calf muscles to pull the heel upwards.
Class - III lever (FER) (Effort is between the fulcrum and the resistance) 	**Resistance:** Weight of the forearm and the weight in the hand. **Fulcrum:** Elbow joint. **Effort:** Contraction of the biceps.



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Some Important Disorders of the Skeletal System

Rheumatism : Any painful state of the supporting structures of the body - such as bones, ligaments, joints, tendons or muscles.

Arthritis : It is a form of rheumatism in which the joints have become inflamed.

Gout : Either the body produces excess uric acid or the person is unable to excrete normal amount of uric acid. This gets deposited in the soft tissues of the joints and eventually destroys the tissues.

Dislocation : Displacement of a bone from a joint with tearing of ligaments, tendons, and articular capsules.

Strain : Overstretching of a muscle.

Sprain : A forcible wrenching or twisting of a joint with partial rupture, or other injury to its attachment. Considerable swelling and pain may occur due to underlying haemorrhage from ruptured blood vessel.

Exercise

1. State five functions of the skeletal system.
2. Name the different types of bones and give one example of each.
3. Match the elements of column A with elements of column B.

A	B
1. Scapula	Longest bone
2. Femur	Collar bone
3. Carpals	Breast bone
4. Clavicle	Shoulder bone
5. Humerus	Wrist bone
6. Sternum	Funny bone
7. Incus	Hammer
8. Malleus	Stirrup
9. Stapes	Smallest bone
10. Hinge joint	Atlas and axis
11. Ball-and-socket joint	Deficiency of Vitamin D
12. Ricket	Age-related removal of calcium from bones
13. Oestoporosis	Wrenching or twisting of muscle or ligament
14. Pivot joint	Patella
15. Sprain	Elbow
16. Knee cap	Hip joint

4. State the type of movement allowed by the following joints and give one example of each:
   (i) Gliding joint (ii) Ball and Socket joint
   (iii) Pivot joint (iv) Hinge joint
5. Name the kind of joint in the human skeleton in which the ends of the two joining bones are lubricated by a fluid. Give two examples of such a joint.
6. Give the number of bones present in the following:
   (i) True ribs (ii) Auditory ossicles (iii) Lumbar vertebrae
   (iv) Pectoral phanges (v) Carpals (vi) Tarsals
7. State three functions of muscles. Explain with the help of suitable examples the terms 'agonist' and 'antagonist' muscles.
8. In producing a body movement, bones act as levers and joints act as fulcrums. Illustrate with an example.
9. Explain briefly :
   (i) Old people are more susceptible to fractures. (ii) Shivering occurs when outside temperatures are low.

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14
The Respiratory System

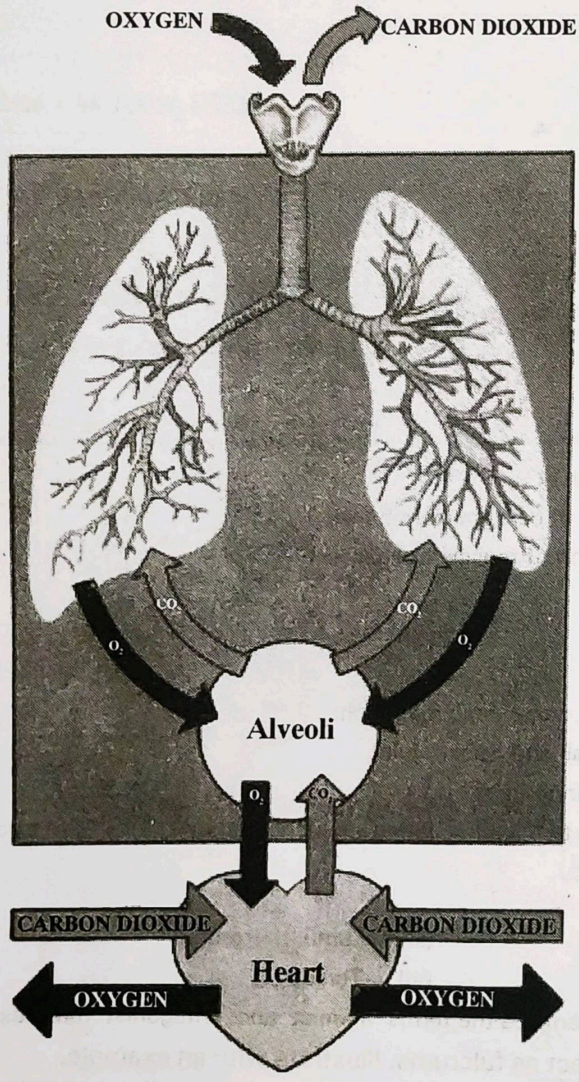
Introduction

'Life' manifests itself in the process of **respiration.** When any organism, whether plant or animal, stops respiring, all its metabolic activities cease and it acquires the characteristics of non-living objects. The organism is then described as 'dead'.

The term respiration combines two ideas:

1. The physical act of breathing during which air is pumped in and out of the system (external respiration).
2. The chemical process of producing energy from food, in the cells themselves (internal respiration).

The energy required to perform metabolic functions comes from oxidation. Oxygen oxidises organic substances in the body of the organism and releases energy.



Since oxygen stores are limited in any organism, the body requires a continuous supply of oxygen from the environment. Simultaneously, the body has to continually eliminate carbon dioxide which is produced as a result of metabolic processes and is toxic when present in excess amounts.

If carbon dioxide is allowed to accumulate in the blood and oxygen supply is reduced, death may follow as can be seen from cases of strangulation and drowning where the respiratory tract is obstructed. This condition, in which blood becomes more venous by accumulation of CO_2, is called **asphyxiation.**

In humans and other higher animals, external respiration takes place in the lungs. The nose (and mouth) is the port of entry for the air. The coordinated action of the **diaphragm, ribs and chest muscles** are responsible for **drawing in the fresh air** (inspiration) as well as for **expelling the waste gases** (expiration).

On reaching the ultimate passages of the respiratory tract (alveoli), the oxygen diffuses out into the blood capillaries (formed by the branching of the pulmonary artery.)

At the same time, carbon dioxide from the blood diffuses into the alveoli. The low concentration of oxygen in the capillaries and the high concentration of oxygen in the inspired air accounts for this gaseous exchange.

The oxygenated blood is taken to the heart from where it enters into the systemic circulation and reaches all the tissues of the body.

The energy produced due to cellular respiration is used in varied activities such as synthesis of proteins from amino acids, production of enzymes, contraction of muscles for movement, conduction of electrical impulse in a nerve cell, production of new cells by cell division, etc.

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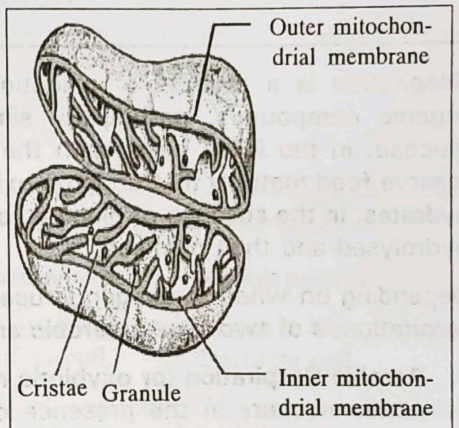
A part of this energy is in the form of the high grade chemical energy **adenosine triphosphate** (ATP). The energy required to carry out any kind of work is provided by ATP. When the energy released in the form of ATP is used up, it is converted to **adenosine diphosphate** (ADP) by the addition of a phosphate group. When more energy is available by further breakdown of glucose, ADP is converted to ATP.

Depending on whether oxygen is used in the process or not, respiration is of two types — **aerobic** and **anaerobic**. Aerobic respiration proceeds in the presence oxygen, while anaerobic respiration proceeds in the absence of oxygen.

The process of respiration takes place in two steps called **glycolysis** and **Krebs cycle.**



The mitochondria in the cell is the seat of respiration

1. **Glycolysis**

   An **anaerobic** process which takes place in the cytoplasm with the help of several enzymes. During this process, glucose is converted to **pyruvic acid.**

2. **Krebs Cycle**

   This is **aerobic** in character and takes place inside the **mitochondria** with the help of enzymes. During this process, pyruvic acid is converted into carbon dioxide and water vapour.

Note

Certain aerobic bacteria are able to oxidise inorganic compounds with the release of energy. These chemical reactions are exothermic, i.e., they proceed with the liberation of heat. The energy released from these reactions is utilised by the bacteria for the synthesis of carbohydrates and other organic compounds. Thus, other than respiration, there are other processes in plants that release energy.

a. **Photosynthesis:** This process is driven by solar energy.

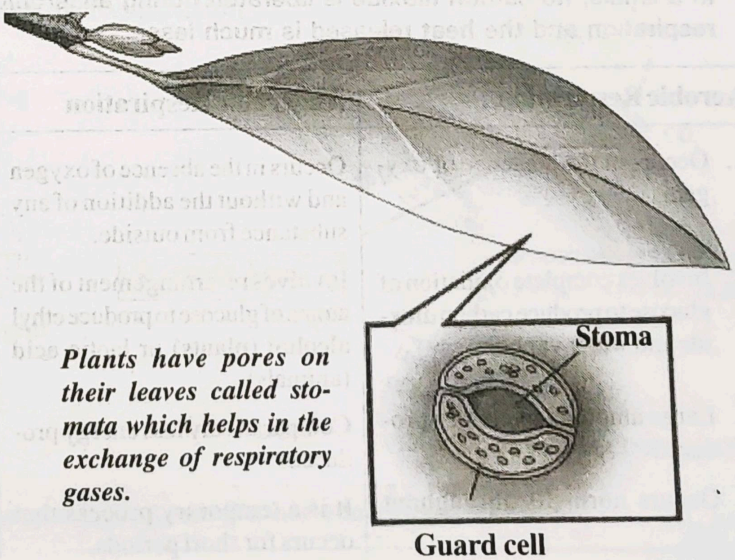
b. **Chemosynthesis:** This process is driven by the energy released by inorganic chemical reactions.

   Example of chemosynthetic bacteria include **nitrifying bacteria** (species of *Nitrosomonas)* which oxidise ammonia to nitrous acid and **nitrating bacteria** (species of *Nitrobacter*) which oxidise nitrous acid to nitric acid.

Gaseous Exchange in Plants

In higher plants, oxygen and carbon dioxide diffuse into and out of roots and stems through the **outer layers of cells.**

* Woody stems have openings called **lenticels** which allows gases to diffuse in and out of the plant body.
* The majority of the gas exchange in plants, however, takes place through small openings in the leaves and herbaceous stems called **stomata.** The loose arrangement of the spongy mesophyll tissues in the leaves gives rise to air spaces inside the leaf which facilitates the efficient exchange of gases.



Plants have pores on their leaves called stomata which helps in the exchange of respiratory gases.

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Types of Respiration

Respiration is a process of oxidation or breaking down of organic compounds, particularly simple carbohydrates like glucose, in the living cells, with the release of energy. The reserve food material that undergo oxidation are simple carbohydrates. In the absence of glucose, proteins and fats are first hydrolysed and then oxidised.

Depending on whether oxygen is used in the process or not, respiration is of two types: **aerobic** and **anaerobic**.

a. **Aerobic Respiration (or oxybiotic respiration):** Aerobic respiration occurs in the presence of oxygen and is represented by the equation given alongside. As can be seen from the reaction, one mole of glucose is completely broken down to yield carbon dioxide and water vapour with the liberation of 420 kcal of energy.

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{enzymes} 6CO_2 + 6H_2O + 38\,ATP + energy$$

b. **Anaerobic Respiration (or anoxybiotic respiration):** Anaerobic respiration takes place in the absence of oxygen and is represented by the equation alongside. From the equation it is clear that there is no addition of any substance from outside. It only involves a rearrangement of the atoms of glucose. Therefore, the process is called **intra-molecular respiration.**

Anaerobic respiration in Plants

$$C_6H_{12}O_6 \xrightarrow{enzymes} 2C_2H_5OH + 2CO_2 + 2ATP + heat\ energy$$

Ethyl alcohol

Anaerobic respiration in Animals

$$C_6H_{12}O_6 \xrightarrow{enzymes} 2C_3H_6O_3 + 2ATP + heat\ energy$$

Lactic acid

It is a normal process in certain microscopic bacteria and fungi. Fruits and seeds also may sometimes respire anaerobically. In most other plants, it is a temporary process. Under adverse conditions, such as flooding, when terrestrial plants are totally submerged in water, aerobic respiration is practically obstructed. The plants then respire anaerobically and hence, survive.

In animals, anaerobic respiration occurs in tapeworms living inside the human intestines, and temporarily when the skeletal muscles are worked during physical exercise. In animals, **no carbon dioxide is liberated during anaerobic respiration and the heat released is much less.**

Aerobic Respiration	Anaerobic Respiration
1. Occurs in the presence of oxygen.	Occurs in the absence of oxygen and without the addition of any substance from outside.
2. Involves complete oxidation of glucose to produce carbon dioxide and water vapour.	Involves re-arrangement of the atoms of glucose to produce ethyl alcohol (plants) or lactic acid (animals).
3. Large amounts of energy produced.	Comparatively less energy produced.
4. Occurs normally throughout life.	It is a temporary process that occurs for short periods.

Fermentation

Under anaerobic conditions certain microorganisms like yeast convert sugar into alcohol and/or into simpler organic substance with the production of carbon dioxide and water vapour. This process which is similar to anaerobic respiration can be shown by the following equation.

$$C_6H_{12}O_6 \xrightarrow{Zymase} 2C_2H_5OH + 2CO_2 + 28\ k\,cal$$

Fermentation is of great commercial importance and is used in the manufacture of alcohol, acetic acid, lactic acid, curing of tobacco and a variety of other commercial products.

Fermentation differs from anaerobic respiration in the following ways:

1. Fermentation occurs in substrates outside the cell.
2. It occurs by the enzymatic action of certain bacteria and fungi (yeast) on the substrate which is in a liquid medium.

A substrate is a substance on which an organism acts and usually derives its nourishment from.

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Energy Production in Respiration

The process of cellular respiration takes place in two steps called **glycolysis** and **Krebs cycle.**

1. Glycolysis

It is an **anaerobic** process which takes place in the **cytoplasm** with the help of several enzymes.

In this phase ATP is converted to ADP. This initiates the process of respiration leading to the formation of phosphoglyceric acid (PGA) and finally pyruvic acid. Thus, during this process, **glucose** is converted to **pyruvic acid** through a chain of intermediate reactions. The following points may be noted:

(i) One molecule of glucose yields two molecules of pyruvic acid.

(ii) The phosphate group as a source of energy is mainly donated by ATP.

(iii) Eight molecules of ATP are formed for each molecule of glucose converted to pyruvic acid.

(iv) Each reaction is catalysed by a specific enzyme.

(v) All the reactions are reversible.

(vi) Pyruvic acid holds an intermediate key position between the two phases of respiration.

Glycolysis	Krebs Cycle
1. Anaerobic process.	Aerobic process.
2. Occurs in the cytoplasm of the cell.	Occurs in the mitochondria of the cell.
3. Converts glucose into pyruvic acid.	Converts pyruvic acid into carbon dioxide and water vapour.
4. Much less energy is produced due to incomplete oxidation.	Energy produced is high due to complete oxidation.

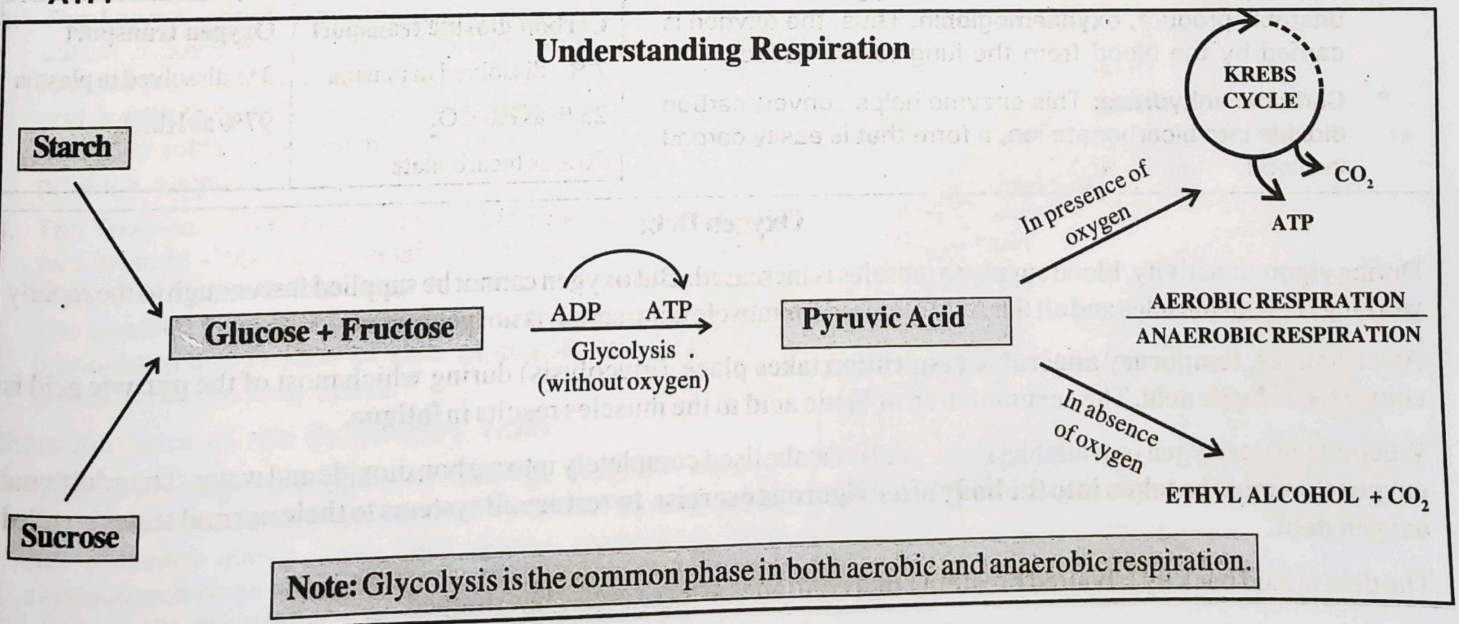
2. Krebs Cycle

This is **aerobic** in character and takes place inside the **mitochondria** with the help of enzymes. During this process pyruvic acid is converted into **carbon dioxide** and **water vapour.** The complete oxidation of one molecule of glucose yields 6 molecules of carbon dioxide and **38 molecules of ATP.**

Energy Production

Glucose	→ Pyruvic Acid	=	8 ATP
Pyruvic Acid	→ Acetyl-CoA	=	6 ATP
Krebs Cycle		=	24 ATP
			38 ATP

Understanding Respiration



Note: Glycolysis is the common phase in both aerobic and anaerobic respiration.

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Stages in Respiration in Mammals

Respiration is a catabolic process by which an organism assimilates oxygen, oxidises organic substances and releases carbon dioxide, water vapour and energy.

Respiration is a complex and continual process resulting in the permanent renewal of blood gases. It occurs in three stages:

a. **External or Pulmonary Respiration:** It involves gaseous exchange between the body (lungs) and the atmospheric air. This includes:

   1. Gas exchange between the atmospheric and alveolar air.
   2. Gas exchange between the blood of the lung capillaries and the alveolar air.

   External respiration is accomplished by the respiratory tract, lungs, pleura, bones and muscles of the thorax, and the diaphragm.

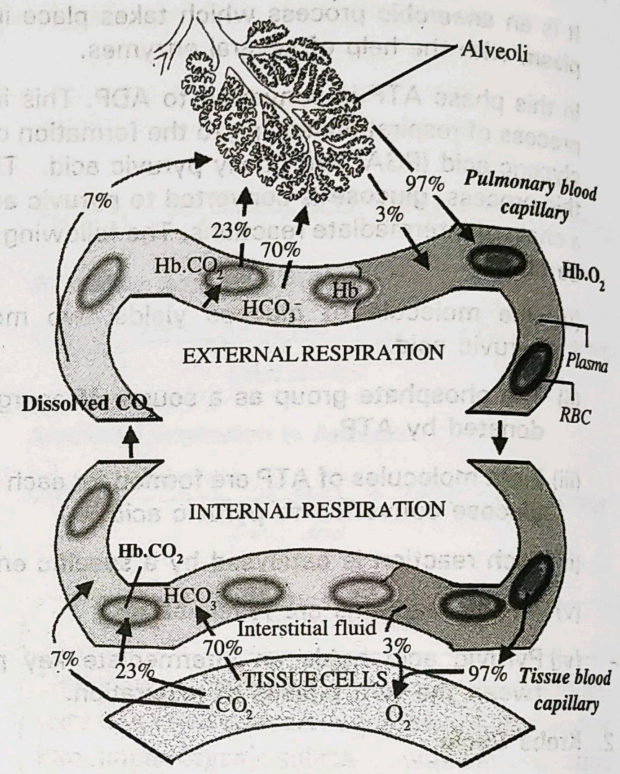
b. **Gas transport provided by the blood:** The oxygen combines with the haemoglobin of the blood and is carried from the lung to the tissues. Carbon dioxide from the cells and tissues is transported to the lungs for elimination.

c. **Internal or Tissue Respiration:** This includes gaseous exchange between the blood and tissue.

   1. Oxygen is given up by the blood to the tissues.
   2. Carbon dioxide is eliminated by the cells and taken up by the blood.

   In mammals, **red blood cells** play an essential role in this process. They contain **haemoglobin**, a red pigment and an enzyme called **carbonic anhydrase.**

   * **Haemoglobin:** It combines with oxygen to form an unstable product, **oxyhaemoglobin.** Thus, the oxygen is carried by the blood from the lung to the tissues.
   * **Carbonic anhydrase:** This enzyme helps convert carbon dioxide into bicarbonate ion, a form that is easily carried in blood.



Transportation of respiratory gases in Respiration	
Carbon dioxide transport	**Oxygen transport**
7 % dissolved in plasma	3 % dissolved in plasma
23 % as $Hb.CO_2$	97% as $Hb.O_2$
70% as bicarbonate	

Oxygen Debt

During vigorous activity, blood supply to muscles is increased. But oxygen cannot be supplied fast enough to the rapidly working skeletal muscles and all the ATP required for muscle contraction is not generated.

At such times, **temporary anaerobic respiration** takes place (glycolysis) during which most of the **pyruvic acid is converted to lactic acid.** The accumulation of lactic acid in the muscles results in **fatigue.**

When adequate oxygen is available, lactic acid is catabolised completely into carbon dioxide and water. The **additional oxygen that must be taken into the body after vigorous exercise to restore all systems to their normal states is called oxygen debt.**

The debt is paid back by laboured breathing that continues after exercise has stopped.

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The Respiratory System in Humans

The respiratory system consists of the **respiratory tract** (i.e., the nose, pharynx, larynx, trachea, bronchi, bronchioles, alveoli) and the **lungs.**

Parts of the Respiratory Tract

1. **The Nose:** The nose is the port of entry for the atmospheric air. Externally it bears two nostrils represented by a cartilaginous septum, and internally it opens into a pair of nasal chambers.

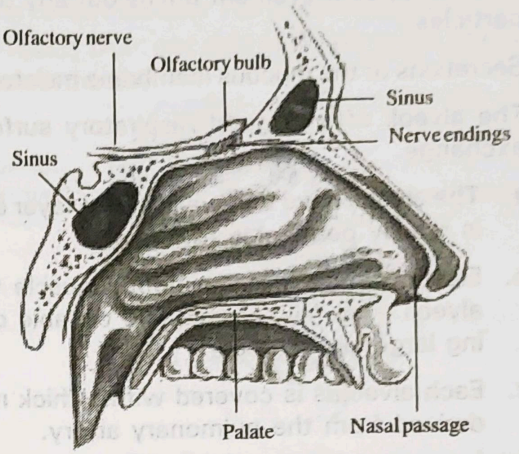
Functions of the Nose

(i) The **hair** lining the nostrils trap and prevent the entry of dust, or any other large foreign particles, into the system.

(ii) The lining of the nasal chamber **secretes a sticky liquid called mucous** which **traps harmful organisms.**

The nasal chamber also acts as a radiator and **warms the air** as it passes over it into the body and **adds moisture** to it.

(iii) The nasal chamber is provided with a special pocket of sensory cells **(olfactory epithelium),** that respond to the stimuli of smell.



Section showing the inner parts of the Nose

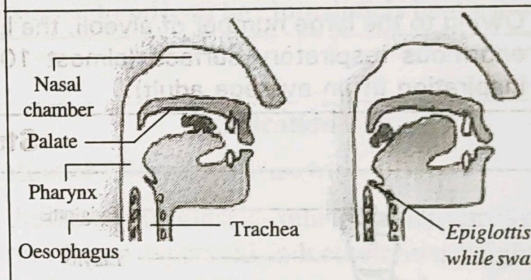
2. **The Pharynx:** The pharynx is a common passage at the back of the mouth for air and food. Air enters the front tube called the **trachea** or wind pipe while food enters the hind tube called the **oesophagus.** The opening of the wind pipe is guarded by a muscular flap called the **epiglottis.** When not in use, the food pipe remains partially collapsed.

   Choking and coughing are reflex actions which tend to remove foreign particles that may accidentally enter the trachea.

3. **The Larynx:** Located at the start of the trachea is a hollow cartilaginous structure called the **voice box.** The voice box is more prominently visible in males at the front of the neck and is popularly called the **Adam's apple.** It consists of two muscular folds called **vocal cords.** Vibrations of these cords produce sounds.

4. **The Trachea:** The trachea divides in the thoracic cavity into two **bronchi** – the right and left, which enter each lung and branch extensively into what is called the bronchial tree. The smallest bronchial branches are called **bronchioles.** The bronchioles end in blind air sacs as **alveoli.** The clusters of alveoli form the lung tissue.

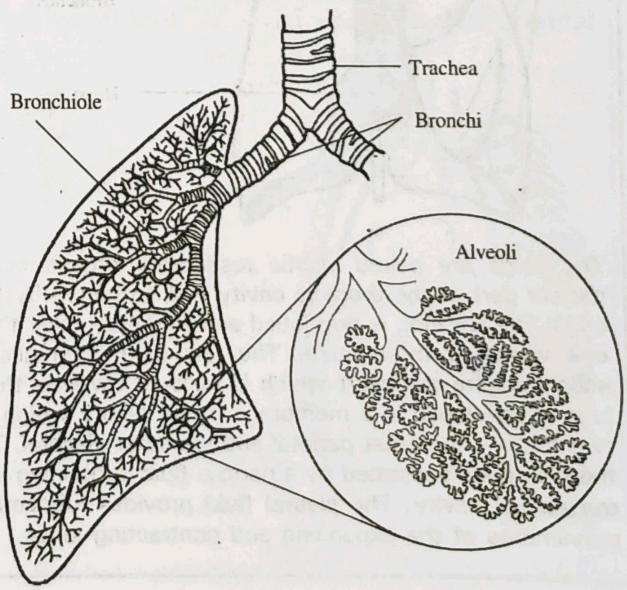
Function of Epiglottis



At the time of swallowing food, the epiglottis closes the tracheal opening, thereby preventing the food from entering the wind pipe.

Characteristics of the Respiratory Tract

1. **Incomplete rings (C-shaped) of cartilage** keep the trachea and bronchi distended and prevent their collapsing when the pressure inside them falls during inspiration. The cartilaginous rings also strengthen the walls of the trachea and bronchi. **Bronchioles are without any cartilage.**



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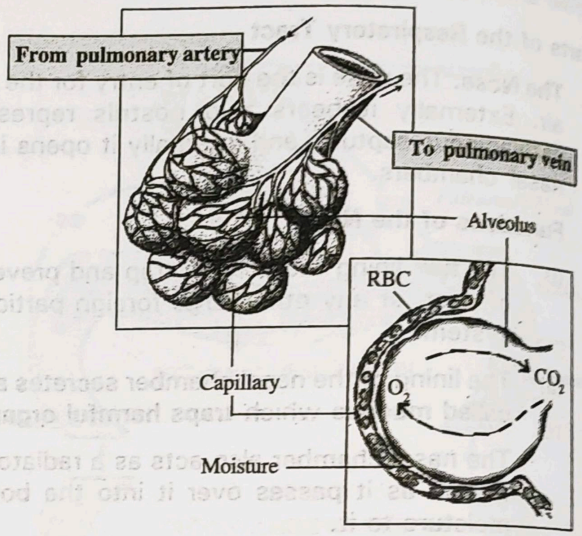
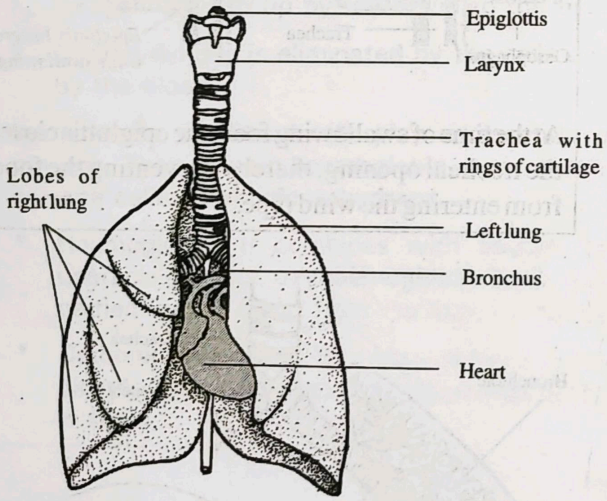
2. The mucous membrane of the trachea, bronchi and bronchioles is lined with a multilayer **ciliated epithelium**, the cilia of which move in the direction of the oral (mouth) cavity. This constant movement drives out any unwanted foreign particles.

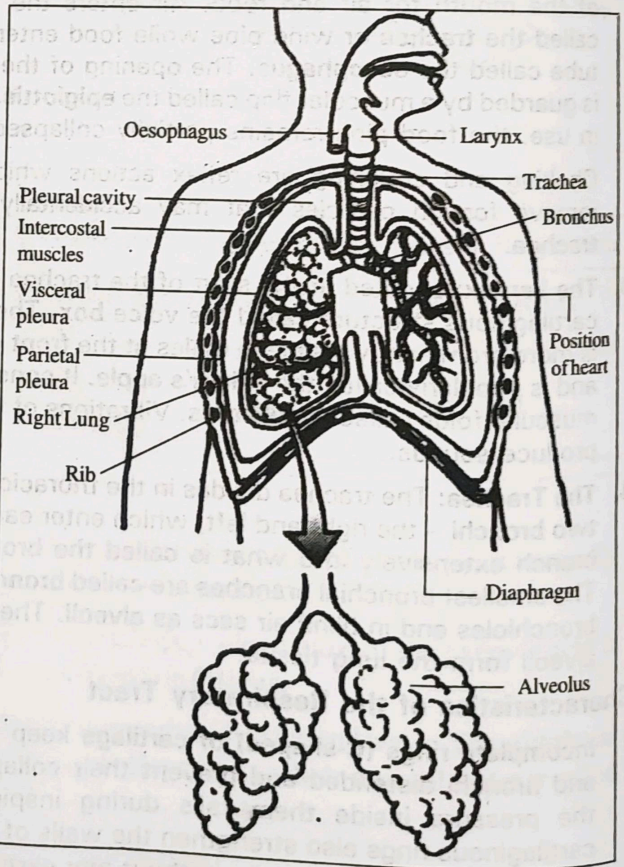
3. Secretions of the mucous membrane moisten the inspired air.
4. The alveoli offer a good respiratory surface for gaseous exchange.
   a. The alveoli have thin walls of one layer epithelium which is readily permeable to gases.
   b. Elastic structure and smooth muscle fibres make the alveoli easily distensible and capable of accommodating large air volumes.
   c. Each alveolus is covered with a thick net of capillaries derived from the pulmonary artery.
   d. The lining of the alveoli is covered with a film of moisture. Oxygen dissolves in the moisture and diffuses through the epithelium and capillary walls into the blood where it combines with the haemoglobin.
   e. Owing to the large number of alveoli, the lungs have an enormous respiratory surface (almost 100 m^2 during inspiration in an average adult).



Both lungs contain 300 to 400 million microscopic alveoli which in a normal adult have a diameter of 0.2 mm.

Structure of the Lungs





The lungs are paired elastic respiratory organs occupying the greater part of the thoracic cavity and protected by the bony rib cage. The left lung is two-lobed and slightly smaller than the right one which is three-lobed. The left lung is smaller so as to accommodate the heart which is inclined towards the left. Each lung is enveloped in a membrane called pleura which consists of two folds — the outer **parietal** and the inner **visceral**. The folds of the pleura are separated by a narrow fluid containing space called the **pleural cavity**. The **pleural fluid** provides lubrication for free movements of the expanding and contracting lungs.

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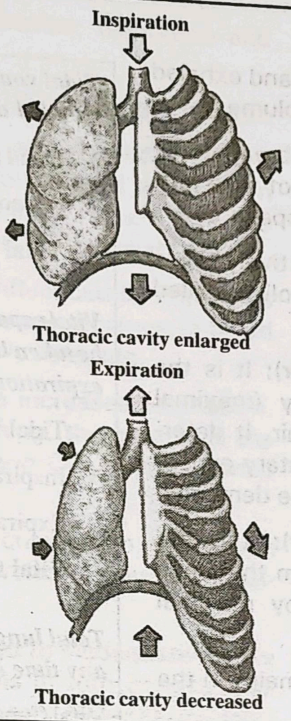
Mechanism of Inspiration and Expiration

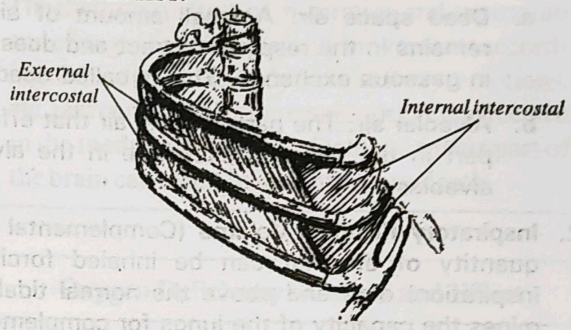
Inspiration: Inspiration of air occurs when the volume of the thoracic cavity is increased. When the volume increases, the pressure in the thoracic cavity becomes lower than the outside atmospheric air. Hence, atmospheric pressure forces air into the lungs through the nose and trachea.

Expiration: When the volume of the thoracic cavity is reduced, the pressure of the air inside the thoracic cavity becomes greater than the outside atmosphere. Hence, air from inside the lungs is expelled through the trachea and nose to equalise the internal and external pressure.

The changes in the volume of the thoracic cavity during inspiration and expiration is brought about by the coordinated contraction and relaxation of the intercostal muscles and the diaphragm.



Intercostal Muscles: The intercostal muscles run obliquely from one side of the rib to the next and connect the ribs.



Diaphragm: The diaphragm is a muscular sheet of tissue extending across the body cavity between the thorax and abdomen. At rest, it is dome-shaped extending upwards into the thoracic cavity. The stomach and liver lie immediately below it.

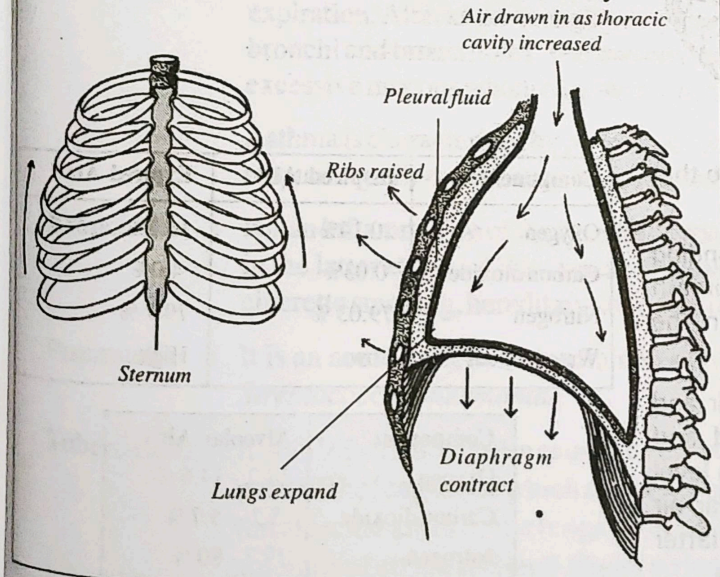
Inspiration

1. Contraction of Intercostal Muscles

When the intercostal muscles contract, the lower portion of the sternum is displaced forward, **raising** the lower **ribs** upwards and outwards.

2. Contraction of Diaphragm

When the muscles of the diaphragm **contract,** the diaphragm flattens from its arched position. This also contributes to the enlargement of the thoracic cavity.



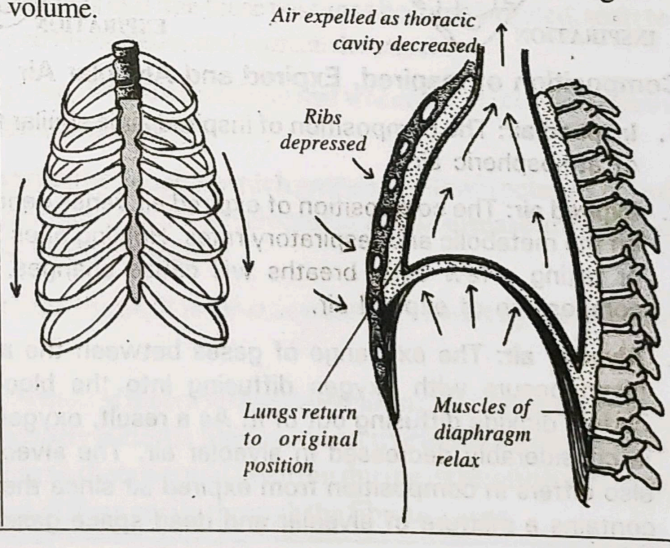
Expiration

Relaxation of Intercostal Muscles

When the intercostal muscles relax, the sternum is pulled in and the ribs are depressed under their own weight, thus reducing the volume of the thoracic cavity.

Relaxation of Diaphragm

The diaphragm relaxes and under pressure from the muscular walls and organs of the abdomen returns to its arched position. The chest returns to its original position and also the lungs, by virtue of its elasticity return to their original volume.



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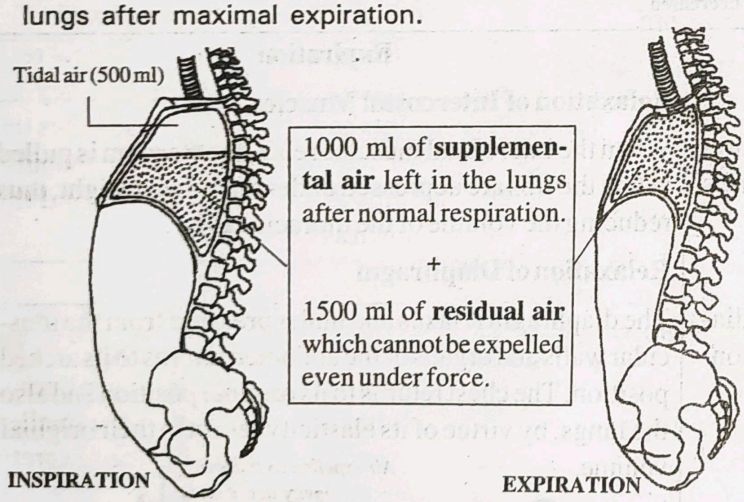
Lung Volumes

There are four major lung volumes:

1. **Tidal Volume:** The amount of air that is inhaled and exhaled during normal quiet breathing is called tidal volume.
   a. **Dead space air:** A small amount of air breathed in remains in the respiratory tract and does not take part in gaseous exchange. This is called dead space air.
   b. **Alveolar air:** The part of tidal air that effectively takes part in the gaseous exchange in the alveoli is called alveolar air.
2. **Inspiratory Reserve Volume** (Complemental air): It is the quantity of air that can be inhaled forcibly (maximal inspiration) over and above the normal tidal air. It determines the capacity of the lungs for complementary expansion which is required in increased gas exchange demands.
3. **Expiratory Reserve Volume** (Supplemental air): It is the volume of air that can be expelled forcibly from the lungs if a quiet inspiration-expiration is followed by maximal inspiration.
4. **Residual Volume:** It is the volume of air that remains in the lungs after maximal expiration.



Tidal voulme is the amount of air that is inhaled and exhaled during normal quiet breathing.

Dead space air	=	150 ml
Alveolar air	=	350 ml
Tidal Air	=	**500 ml**

Vital capacity of the lungs is the volume of air that can be taken in and expelled by maximum inspiration and expiration.

Tidal Volume	=	500 ml
Inspiratory Reserve Volume	=	3000 ml
Expiratory Reserve Volume	=	1000 ml
Vital Capacity of Lung	=	**4500 ml**

Total lung capacity is the maximum air which can at any time be taken in the two lungs.

Vital Capacity	=	4500 ml
Residual Volume	=	1500 ml
Total Lung Capacity	=	**6000 ml**

Note: Lung volumes are subject to large variations. Average values have been given here

Composition of Inspired, Expired and Alveolar Air

1. **Inspired air:** The composition of inspired air is similar to that of atmospheric air.
2. **Expired air:** The composition of expired air varies depending on the metabolic and respiratory rates. Holding ones breath or taking a few deep breaths will cause changes in the composition of expired air.
3. **Alveolar air:** The exchange of gases between the air and blood occurs with oxygen diffusing into the blood and carbon dioxide diffusing out of it. As a result, oxygen level is considerably decreased in alveolar air. The alveolar air also differs in composition from expired air since the latter contains a mixture of alveolar and dead space gases.

Component	Inspired Air	Expired Air
Oxygen	20.14%	16.3%
Carbon dioxide	0.03%	4.0%
Nitrogen	79.03 %	79.7 %
Water vapour	Low	High

Component	Alveolar Air
Oxygen	14.2 - 14.6 %
Carbon dioxide	5.2 - 5.7 %
Nitrogen	79.7 - 80 %

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The Respiratory Cycle

The respiratory cycle consists of inspiration, expiration and respiratory pause.

In adults, the respiratory rate is 12-18 breaths per minute.

Children breathe more superficially and therefore have a higher respiratory rate. The respiratory rate of a new born can be as much as 60 breaths per minute. At any age, the respiratory rate is 4-5 times lower than the heart rate.

The depth and rate of breathing is influenced by numerous factors such as emotional or mental state, changes in blood chemistry, physical fitness, metabolic rate, etc.

The slightest rise of carbon dioxide increases respiration. The greater the depth of the breathing, the greater is the amount of O_2 that is supplied to, and CO_2 that is carried away from the lungs.

In progressive asphyxia, with accumulation of carbon dioxide, respiratory convulsions develop, followed by collapse and death.

Slow and shallow breathing may lead to inadequate supply of oxygen to cells and tissues. This in turn impairs their functioning as can be seen in respiratory diseases and from the effect of altitude.

As the altitude increases, the pressure decreases resulting in a decreased supply of oxygen.

At altitudes above 5,000 m above sea-level, one could easily suffer from dizziness and black outs accompanied by impaired vision and muscular coordination.

Respiratory Centre

The rhythmic pattern of inspiration and expiration and changes in the respiratory movements according to the state of the body (rest, activity, emotions, etc.) are controlled by the respiratory centre located in the **medulla oblongata**. Damage to this part of the brain can result in instantaneous death.

Oxygen Deficiency - Causes and Effect

A lack of oxygen availability may be due to a lowered oxygen content of the air, obstruction to the air passage, lung disease, inability of the blood to carry its full quota of oxygen (as in haemorrhage or anaemia, or when the haemoglobin is locked up by carbon monoxide), and when the blood circulation is slowed in heart failure.

All these results in overbreathing (panting) at rest, in an effort to make up for the deficiency by increasing the intake of air. In all these states the blueness of insufficiently oxidised haemoglobin is evident in the lips and under the nails- and the condition is known as **cyanosis.**

Some Common Respiratory Diseases

Asthma : The air passages of the bronchi and bronchioles are narrowed and the alveoli may remain open during expiration. Attacks are brought on by spasms of the smooth muscles that lie in the walls of the smaller bronchi and bronchioles. The mucous membranes that line these passages become irritated, secrete excessive mucous which clog the bronchi and bronchioles and worsen the attack.

Asthma is characterised by periods of coughing, difficult breathing and wheezing. It is caused due to respiratory allergies or may be psychosomatic in origin.

Bronchitis : It is an inflammation of the bronchi characterised by cough in which greenish-yellow sputum is raised in the latter stages of the disease. Factors influencing the development of this disease are allergy, cigarette smoking, hereditary, air pollution, lack of immunity.

Pneumonia : It is an acute infection or inflammation of the lungs. It is most commonly caused by the bacteria *Streptococcus pneumoniae.*

Tuberculosis : It is an infectious disease caused by the bacterium *Mycobacterium tuberculosis.* The bacteria destroy parts of the lung tissue which are then replaced by inelastic fibrous connective tissue. Being inelastic, the affected areas of the lungs do not return to their normal position during expiration and larger amounts of air are retained. Gases no longer diffuse easily through the fibrous tissue.

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Exercise

1. Differentiate between:

(i) Pulmonary respiration and Tissue respiration

(ii) Right lung and Left lung

(iii) Trachea and Oesophagus

(iv) Larynx and Pharynx

(v) Inspired air and Expired air

2. List three requirements of a good respiratory surface.

3. State the function of:

(i) Nose

(ii) Epiglottis

(iii) Haemoglobin

(iv) Ciliated epithelium lining the respiratory tract

(v) The pleural fluid

(vi) Diaphragm

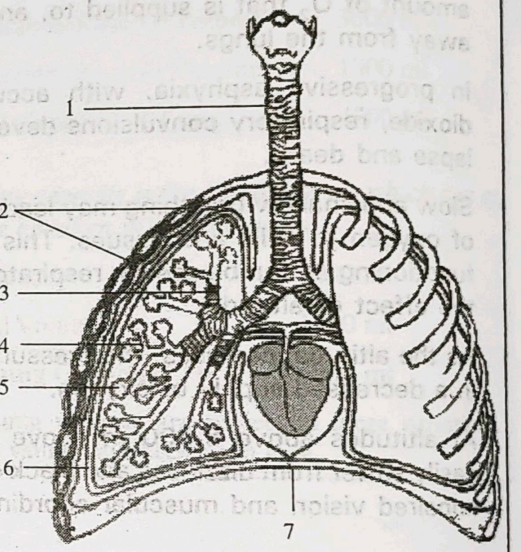
(vii) Larynx

(viii) Alveoli

(ix) Incomplete rings of cartilage in the trachea and bronchi.

4. Explain the role of the diaphragm and the intercostal muscles in the mechanism of inspiration and expiration.

5. The diagram alongside represents the human respiratory organs.



(i) Label the parts 1 to 7 to which the guidelines point.

(ii) How is the part 1 supported?

(iii) What is the function of the part labelled 5?

(iv) Describe briefly the blood supply to and from the lungs.

(v) How does the gaseous exchange take place?

(vi) How is the thoracic cavity enlarged?

(vii) Name all the parts that are not shown in the diagram, but which belong to the respiratory tract.

6. Name:

(i) A respiratory pigment.

(ii) An animal and a plant that respire anaerobically.

(iii) The condition in which the oxygen supply to the respiratory system is cut off.

(iv) The parts that belong to the respiratory tract.

(v) The membranes enveloping the lungs.

(vi) The ultimate passages of the respiratory tract.

(vii) The part of the tidal air that effectively takes part in the gaseous exchange in the lungs.

(viii) The part of the brain where the respiratory centre is located.

(ix) The small amount of air inhaled that remains in the respiratory tract but does not take part in the gaseous exchange.

7. In each of the following cases, pick out one term which includes the other three:

(i) glucose, oxygen, energy, oxidation

(ii) ethyl alcohol, carbon dioxide, anaerobic, oxygen absent

(iii) diffusion, respiratory gases, alveoli, capillary network

(iv) respiratory tract, trachea, bronchus, alveolus

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8. **Write the approximate values of the following, in the units specified:**

(i) Tidal air **(ml)**

(ii) Oxygen in alveolar air **(percentage)**

(iii) Carbon dioxide in inspired air **(percentage)**

(iv) Total number of alveoli in a normal adult **(millions)**

(v) Volume of air that remains in the lungs after maximal expiration **(litres)**

(vi) Altitude above which dizziness and blackouts are common. **(metres)**

9. **Name the part(s) of the respiratory tract that:**

(i) Serves as a common passage for food and air.

(ii) Is composed of a single layered epithelial tissue.

(iii) Has cartilagenous rings

(iv) Is lined with ciliated epithelium

(v) Is lined with hair

(vi) Encloses the vocal cords

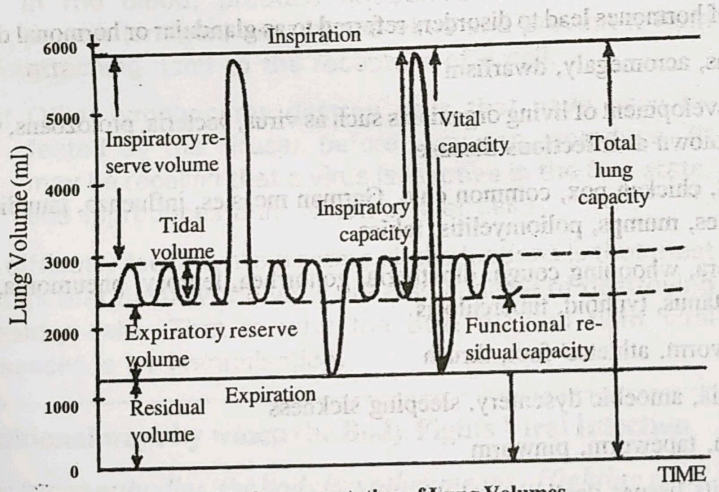
(vii) Constitutes the ultimate passages of the tract.

(viii) Are formed by the division of the wind pipe as they enter the lungs.

(ix) Is involved in the process of gaseous exchange with the lungs.

10. Compare the respiratory mechanism in green plants with that of a mammal.

11. The following diagram shows a group of the lung volumes and capacities. Study the graph carefully and explain briefly the following:



Graphical representation of Lung Volumes

(i) Tidal Volume

(ii) Inspiratory Reserve Volume

(iii) Expiratory Reserve Volume

(iv) Residual Volume

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15
Health and Hygiene

Introduction

The scientific study of the causes of disease is known as **aetiology**. The success of this science lies in the fact that today doctors recognise thousands of disorders and are able to treat a majority of them.

The table below lists the various types of diseases, grouped in convenient categories.

*A **disease** is an abnormal condition of an organism or part, especially as a result of infection, inherent weakness or environmental stress, that disturbs the normal physiological functioning of the organism.*

Type of Disease	Causes and Examples
1. Congenital	Congenital causes act within the womb and cause disorders which are usually obvious at birth. The causes could be due to fault in the chromosomal structure, or damage inflicted to the developing embryo. These include effect of radiations, diseases contracted by the mother (German measles); use of certain drugs (thalidomide); excessive smoking and alcohol intake by the pregnant mother. *Example:* Hare-lip, clubfoot, mongolism, spastic paraplegia
2. Hereditary	Diseases that are transmitted from parent to offspring from generation to generation are **hereditary** diseases. *Example:* Haemophilia, albinism
3. Dietary deficiency	A diet lacking in nutrients such as proteins, essential vitamins or minerals result in deficiency diseases. *Example:* Scurvy, rickets, beri-beri, anaemia
4. Hormonal	Undersecretion or over secretion of hormones lead to disorders referred to as glandular or hormonal disease. *Example:* Goitre, diabetes mellitus, acromegaly, dwarfism
5. Infectious	Disease caused by the entry and development of living organisms such as virus, bacteria, protozoans, worms or fungi into the body tissue, is known as **infectious disease**. *Example:* **Virus** : AIDS, chicken pox, common cold, German measles, influenza, jaundice, measles, mumps, poliomyelitis, rabies **Bacteria** : Cholera, whooping cough, diphtheria, gonorrhea, leprosy, pneumonia, syphilis, tetanus, typhoid, tuberculosis **Fungi** : Ringworm, athletes' foot, thrush **Protozoan** : Malaria, amoebic dysentery, sleeping sickness **Worms** : Filaria, tapeworm, pinworm
6. Degenerative	The ability of the body to repair its tissues declines and the damage outstrips repair. The symptoms of degenerative disease appear with advancing age. *Example:* Graying of hair, baldness, presbyopia, cataract, osteoarthritis, parkinson's disease, arteriosclerosis
7. Immunological	The immune defences of the body provide protection against infections. Sometimes, the defences become directed against the body's own tissues and cause abnormal responses. **Allergies** are included in this group. *Example:* Hay fever, asthma, rheumatoid arthritis, nettle rash
8. Neoplastic (Tumours)	Neoplastic (new growth) diseases are associated with the growth of tumours. It is the extra growth of tissues that bring on the symptoms. Hence the underlying causes for the tumours are not often known. *Example:* Warts, moles (harmless), cancer (generally fatal)

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Infectious Diseases

Of the many types of diseases prevalent, only the infectious diseases are transmissible from person to person, since the agents that cause them easily gain entry into the body through air, water and food. These disease-producing organisms are called **pathogens**. In infectious disease, the pathogen takes over the body's cells and tissues and utilises them for their own growth and reproduction. As a result, the host cells are destroyed and the condition is manifested as a disease.

When a pathogen enters the body, a series of reactions is set up. The outer body wall of the pathogen contains a chemical substance (generally proteins) called **antigens,** which stimulates the production of **antibodies** by the blood surrounding the invading antigen.

a. **Bacterial infection:** In case of bacterial infection, these antibodies kill or weaken the invaders. If the pathogen produces or releases toxic (poisonous) substances into the blood, the blood counters it by producing certain antibodies called **antitoxins**. These neutralise the harmful effects of the toxins. Often the body is unable to produce its own antitoxins rapidly enough. In such cases, antitoxins are artificially administered by the physician.

b. **Viral infection:** In case of viral infection, the body protects itself in the following ways:

(i) The lymphocytes, a type of white blood cells present in the blood, produce antibodies which cover the protein (antigen) coat of the virus and prevent it from attaching itself to the receptors of a cell.

(ii) Other lymphocytes destroy cells that have been infected by the viruses before they can reproduce. (It may be recalled that a virus is inactive in the free state, and reproduces only within a host cell.)

A difficulty faced while treating viral infections is that most drugs that destroy the virus are also capable of destroying healthy cells. That is why the best way to fight viral diseases is by **immunisation**.

Additional ways by which the Body Fights Viral Infection

Apart from antibodies, the body has other means of fighting viral infections.

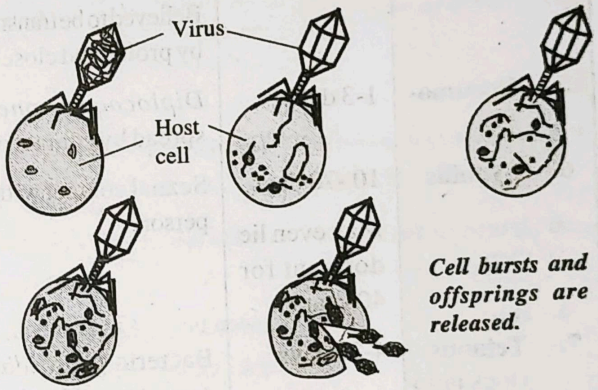
1. *The body produces a high fever which limits the ability of the virus to reproduce.*
2. *In case of cold, large amounts of mucus is formed in the nose and throat which traps the virus and expels them by sneezing and blowing the nose.*
3. *The body also produces a protein called interferon that provides protection against a broad spectrum of viruses.*

1. **Communicable (infectious) diseases** are those which can be transmitted from person to person and are caused due to disease germs called pathogens. They are generally spread by air, water, milk, food or by touch.

   Example: Cold, conjunctivitis, chicken pox, measles

2. **Non-communicable (non-infectious) diseases** are those that cannot be transmitted from person to person.

   Example: Coronary heart disease, cancer, allergy deficiency diseases, etc.



A virus infects a bacterial cell, destroys the bacterial chromosome and replicates itself.

Edward Jenner *was a English physician who coined the word* ***"vaccination"*** *to describe the use of the cow pox inoculation to obtain immunity to small pox.*

He discovered that by treating people with cow pox, they were immune to small pox.

Vaccine	Serum
It consists of dead or weakened bacteria or virus that stimulate the production of antibodies by the blood.	Consists of antibodies that have been produced in the body of another person or animal who has gained immunity, and then injected into the patient.

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Bacterial Diseases

Disease	Incubation	Mode of Transmission	Symptom	Prevention and Cure
1. **Cholera**	Few hours to 6 days	Caused by bacterium *Vibrio comma*, transmitted through food, water, which are contaminated by dust and flies.	Intestinal tract affected. Vomiting, loose motions, reduced urination, dehydration.	Proper sanitation, food should be covered. Control of flies. Anticholera injection
2. **Diphtheria**	2-5 days	Discharge from the throat of infected person by sneezing, coughing.	Occurs generally in children. Throat is affected. Often fatal.	Vaccination: **Triple vaccine (DTP)**
3. **Gonorrhea**	3-4 days	Sexual contact with infected person.	Irritation of sex organs, discharge of pus. May cause infertility in females if fallopian tube is infected.	Avoid sexual contact with infected individuals. Antibiotics e.g., **penicillin**
4. **Leprosy**		Caused by *Hansen's bacillus*. Believed to be transmitted only by prolonged close contact.	Produces trivial alterations in the tissue or gross deformities.	Vaccine
5. **Pneumonia**	1-3 days	*Diplococcus pneumoniae* spread by contact or by air.	Inflammation of one or both lungs.	Antibiotics, e.g., **penicillin**
6. **Syphilis**	10 -70 days. May even lie dormant for 40 years.	Sexual contact with infected person.	Sores usually on sex organs followed in 3-6 weeks by sores in mouth.	Avoid sexual contact with infected persons. Antibiotics, e.g., **penicillin**
7. **Tetanus** (lock jaw)	4-20 days	Bacteria *Clostridium tetani* enters body (blood stream and nerves of spinal cord) through deep wounds or cut in the skin.	Muscular spasms as the normal control of muscle action is hindered. In the last phase jaws lock. Death results.	Prevention by previous vaccination or antitoxin after getting wound.
8. **Typhoid**	7-21 days	Bacteria *Salmonella typhi* passes out through the excreta of infected person. Flies and direct contamination of food especially milk, spread the disease.	Intestines affected. Continuous fever, rises in the afternoons. Reddish eruptions appear on the chest and abdomen. Relapse is common.	Proper sanitation, control of flies, anti typhoid inoculation to be taken every year.
9. **Tuberculosis**		*Mycobacterium tuberculosis* rod-shaped bacteria spread by air, dust, sputum of infected person.	Generally affects lung tissue but may spread throughout the body. Breathlessness, pain, phlegm.	**BCG vaccination.** Immunising of milking herds with tuberculin vaccine. Treatment: **Streptomycin**
10. **Whooping cough**	10-15 days	Caused by bacterium *Haemophilis pertussis and* spread by discharge from throat of infected person.	Occurs mostly in children. Spasms of coughing interspersed with deep, noisy inspiration.	**Triple vaccine**. (A combined vaccine administered to babies to protect against diphtheria, tetanus and whooping cough. Also called DTP).

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Viral Diseases

Disease	Incubation	Mode of Transmission	Symptoms	Prevention and Cure
1. **AIDS** (Acquired immune deficie-ncy syndrome)	12 years	Sexual contact and blood transfusions spread the virus known as HIV.	Loss of weight, general debilitation as body's normal defence against infection breaks down.	Avoid sexual contact with infected person. Cure not yet known. Fatal.
2. **Chicken pox**	14-20 days	Contact with infected person, use of personal articles of infected person.	Skin rashes form crusts. Fever, headaches, general discomfort.	No preventive measure. Attack gives permanent immunity.
3. **Common cold**	1-3 days	Through moisture droplets released by the infected during sneezing and coughing. Contact with personal articles soiled by nasal discharge.	Profuse nasal discharge often accompanied by headache. Body's resistance to germs reduced.	Infected person must cover mouth and nose while sneezing or coughing. Rest and avoidance of chilling.
4. **German measles**	14-21 days	Contact with infected person.	Headache, enlarged lymph nodes, cough, sore throat, rash.	Vaccine. Attack gives permanent immunity.
5. **Influenza**	24-72 days	Spreads by discharges from nose and throat.	Fever, chills, muscular aches and pains.	Vaccine effective only for a few months.
6. **Jaundice** (Infectious hepatitis)		Exposed unhygienic food and fluids.	Loss of appetite, yellowish colouration due to excess bilirubin (bile pigment) in the blood since liver cells are inflamed and unable to function normally.	
7. **Measles**	10-14 days	Contact with infected person.	Fever, rash, red watery eyes, runny nose	Vaccine
8. **Mumps**	12-26 days	Person to person contact.	Chills, headache, fever, swollen parotid (salivary) glands in neck.	Vaccine. Gamma-globulin protects after exposure.
9. **Poliomyelitis**	Paralytic 9-13 days Non-paralytic 4-10 days	Spread by secretions of nose, throat and excreta. Incubates in the intestine and reaches the brain through the blood stream.	Fever, sore throat, muscular pain, stiff back, paralysis of leg affects children. Mild attack may go unnoticed.	Salks vaccine gives permanent immunity.
10. **Rabies**	30 days or more	A canine disease. Transmitted to humans by bite of mad dog (saliva contains virus).	Hydrophobia, virus selectively attacks the brain (nervous system)	Vaccine (first developed by Louis Pasteur). No cure once disease spreads. Dogs can be immunised.

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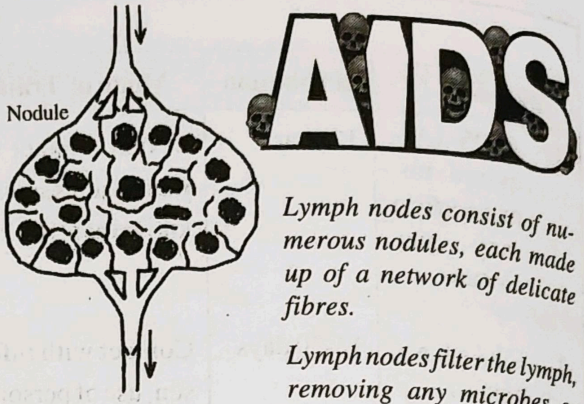
What is AIDS

The immune response is produced by a variety of white blood cells called lymphocytes. There are two types of lymphocytes:

1. The B-lymphocytes which circulate in the blood and produce antibodies and attach themselves to antigens.
2. The T-lymphocytes in which the cell itself is involved in the defence.

In 1981, a serious threat to the immune system was recognized - **Acquired Immune Deficiency Syndrome** (AIDS). AIDS describes the collection of infections that result after acquiring the **Human Immunodeficiency Virus** (HIV).

The retrovirus-HIV attacks the immune system itself. The virus penetrates the T-lymphocyte and takes over the genetic material, using it to produce more virus particles. As the host cell dies, it releases the new virus particles into the blood to infect more cells. The destruction of a person's T-cells reduces the body's defence against infections (for example, pneumonia) and cancers, such as Kaposi's sarcoma.



A lymph node

Lymph nodes consist of numerous nodules, each made up of a network of delicate fibres.

Lymph nodes filter the lymph, removing any microbes or pathogenic organisms.

Symptoms

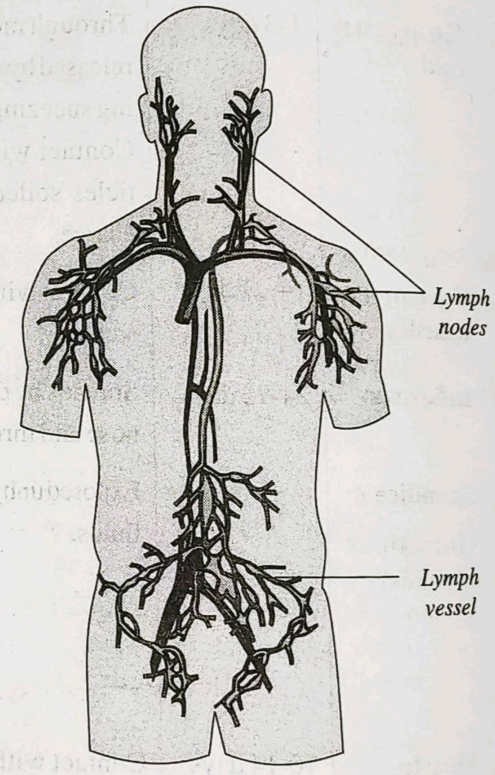
Once a person becomes infected that person is infectious for life. The initial infection is usually without symptoms, and the interval between infection and the first appearance of symptoms is 1-10 years.

(i) Swollen lymph nodes.

(ii) Weight loss, night sweats and susceptibility to other diseases due to break down of the immune system.

(iii) Decreased blood count causing haemorrhage and fever.

Some 50% of the infected people develop the full-blown disorder. About 30% develop the AIDS-related complex (ARC) featuring weight loss, thrush, diarrhoea and fever. In over 50% of cases the brain is affected.



Lymphatic System

Treatment

There is no effective treatment for AIDS yet.

Prevention

HIV is only transmitted by an exchange of body fluids from an infected person to another. Common modes of transmission are sexual intercourse, through sharing needles to inject drugs, blood transfusion and from infected mother to unborn foetus.

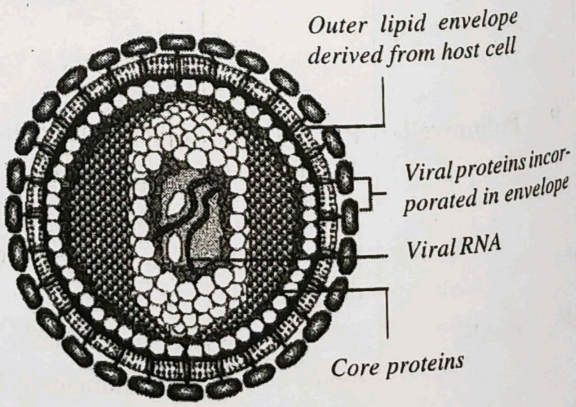
Hence the following precaution should be exercised:

(i) Common razor blades should not be used for shaving.

(ii) Disposable needles and syringes should be used in hospitals.

(iii) Blood donors should be tested for the HIV virus.

(iv) Sexual contact with unknown persons should be avoided.



HIV virus with its Lipid envelope

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Diseases caused by Parasites

1. Mould and Fungi

The microscopic spores of the mould and other fungi infest the outer skin layer and grow by feeding on the dead cells and skin secretions. They usually inhabit humid, protected regions of the body such as armpits, groin, hair and feet. Mouth and vagina in women can also be colonised by fungi.

These fungal infestations are not usually harmful, although they cause a great deal of irritation. Some common fungal diseases are discussed below:

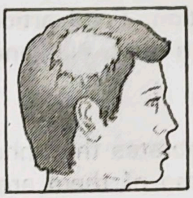
a. **Athletes' foot:** This is a common infection of the skin especially between the toes. The affected skin becomes white and peels off to reveal a red raw area.

b. **Ringworm:** Ring-shaped lesions appear on the skin, especially of the scalp and nails. The affected region becomes discoloured and is covered by scales and vesicles. Being a highly contagious disease, contact with the personal articles of the person suffering from ringworm, must be avoided.

c. **Thrush:** White patches appear on the throat, tongue, lips and palate in young children. The same fungus, *Candida albicans* (or thrush), also causes vaginal infestation in women.

Athlete's foot

This contagious fungal disease usually infects the skin of the feet and causes itching, blisters and cracking.



Ringworm of the scalp

Also a fungal infection, ringworm causes lesions of the scalp and loss of hair from the affected areas.

Two Common Fungal Diseases

2. Protozoa

a. **Malaria:** Caused by a parasitic protozoan *Plasmodium*, malaria is transmitted from person to person by the bite of the female *Anopheles* mosquito.

When a mosquito bites an infected person, the protozoa are sucked up into the stomach of the insect, along with the blood, where they breed. Within ten days their offsprings can be found in the salivary glands of the mosquito. Now if the mosquito bites a person, a dose of the parasite is injected into that person. These reproduce in the RBCs of humans, and destroy them.

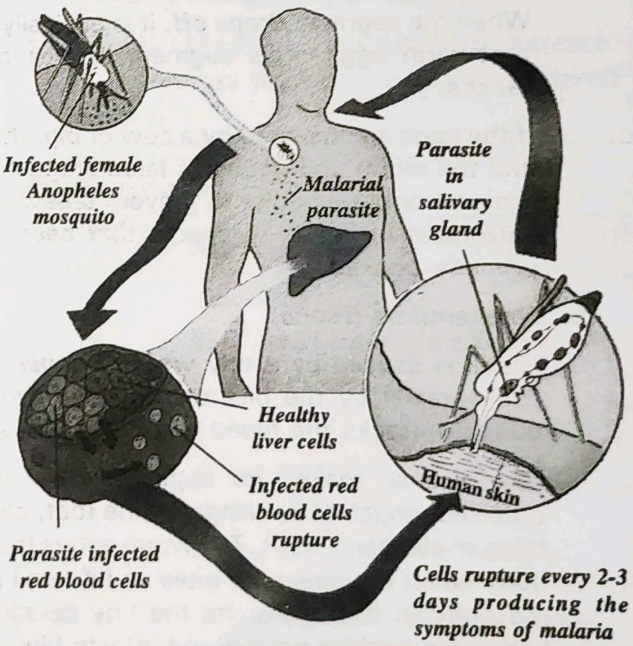
The main symptoms of malaria are high fever, headache and violent shivering (rigours). The fever is repeated on the third or fourth day. Treatment is with drugs like **chloroquine** but prevention is a better solution.

Preventive measures include:

(i) Killing the mosquitoes and destroying their breeding places. An effective **biological control** method has been recently developed. The aquatic bacteria on which the larvae feed are genetically engineered to produce toxins which destroy the larvae.

(ii) Preventing the mosquitoes from biting people.

(iii) Administration of protective drugs.



The Malaria Cycle

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b. Amoebic dysentery

An amoeba called *Entamoeba hystolytica* causes amoebic dysentery. It resides in the large intestine and destroys the lining of the intestinal wall. The infection is accompanied by griping abdominal pain, diarrhoea, discharge of mucus and sometimes blood with the stools.

Contaminated food spreads the infection and flies and cockroaches are the chief vectors (carriers) of the infection. Hence, **hygienic conditions** must be maintained with **proper sanitation. Food articles** must be **covered and protected** from dust, flies and roaches.

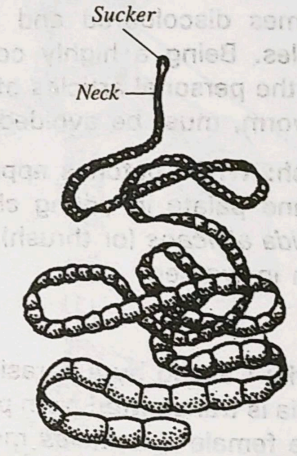
3. Worms

Worms are soft-bodied invertebrates that inhabit the waters and moist soil. While some of them are free living, many are parasitic and cause diseases in humans and in animals. A few important diseases are discussed here.

a. Tape-worm: This is a flat, worm which makes the human intestine its home. It feeds on the digested food available in the intestines, thereby depriving the host of vital nutrients. Hence, the host becomes weak while the worm grows to lengths of several feet.

The worm enters the body through infected beef or pork and lodges in the intestines. The tapeworm absorbs nutrients through its skin as the food being digested by the host flows past it. Older segments are pushed toward the tip of the tail as new segments are produced by the neckpiece. By the time a segment has reached the end of the tail, only the reproductive tract is left. When the segment drops off, it is basically just a sac of tapeworm eggs. This segment passes out with the faeces.

If the eggs are ingested by a cow or pig, the eggs hatch and the worm undergoes its larva stage in the body of the cow or pig. In order to prevent tapeworm infection, care must be taken to ensure that beef and pork are properly cooked.



Tape worm

b. Elephantiasis (Filaria)

Filaria is caused by a tiny worm *Wuchereria bancrofti* and spreads by the bite of the culex mosquito. This disease attacks the blood and lymphatic system.

The disease makes its appearance in the form of outsized, ungainly swellings on the foot, almost resembling an elephant's legs. The worm enters the mosquito's body when the mosquito bites an infected person. The mosquito in turn transmits the tiny parasites into the body of a healthy person and infects him.

The disease can be controlled by destroying the mosquitoes or preventing mosquito bites.

The disease filaria manifests itself in the form of outsized and ungainly swelling of the legs.

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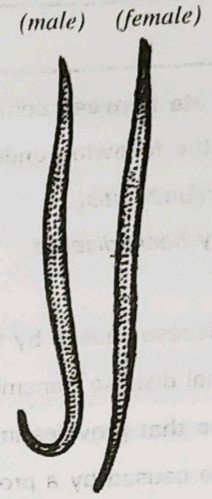
c. Round worm *(Ascaris)*

This cylindrical worm lodges in the human intestine and feeds on the ready-made food. The female lays millions of eggs per day, which pass out with the faeces and reach the soil.

The migration of the larvae through the human lungs causes the blood vessels of the lungs to haemorrhage, accompanied by accumulation of fluids in the lungs. This results in **"ascaris pneumonia,"** which can be fatal.

Farmers and gardeners who are constantly handling soil are most susceptible to this infection. The eggs are picked up by the fingernails from the soil and enter the body when food is eaten with unwashed hands. Therefore, **personal hygiene** is of utmost importance in preventing this infection.



Ascaris

d. Pinworm

These are extremely tiny, rice-like worms which breed in abundance in the human rectum. The female lays the eggs in the anus which causes much irritation and itching. Scratching of the anus transfers the eggs to the fingernails and even scatters them around. The use of personal articles and clothing of infected persons spreads the disease.

4. Mites

Scabies is a highly contagious skin disease caused by a microscopic mite *Sarcoptes scabei*. The parasite burrows into the skin and lays its eggs in warm, moist regions like the groin, and between the fingers and toes. Scratching further adds to the discomfort.

Personal hygiene is an important factor in preventing the spread of this disease. Also, direct contact with the affected person and his personal belongings must be avoided.

Points to Note

The spread of diseases can be described in the following terms:

1. **Endemic:** The disease is specific to a particular region or locality and tends to recur. For example, malaria.
2. **Epidemic:** The spread of disease is rapid and extensive. The outbreak of a contagious disease like plague or of SARS.
3. **Pandemic:** The epidemic is spread over an especially wide geographical area.
4. **Sporadic:** The disease is isolated in occurrence, i.e., it appears singly or at widely scattered localities.

Some Important Insect-Borne Diseases

Disease	Host	Pathogen
1. Malaria	Anopholes mosquito (female)	*Plasmodium* (protozoa)
2. Filaria	Culex mosquito	*Wuchereria bancrofti* (round worm)
3. Yellow fever	Aedes mosquito	Virus
4. Encephalitis	Aedes and Culex species	Virus
5. Sleeping-sickness	Tsetse fly	*Trypanasoma* (protozoa)
6. Bubonic plague	Rat flea	*Pasteurella pestis* (bacterium)
7. Typhus	Flea, lice, mite	Microorganisms of genus *Rickettsia*
8. Cholera	*These diseases are spread by the contamination of food and water by houseflies and cockroaches. These insects visit garbage, manure, faeces, and pick up germs on their bodies which they transfer onto human food and eatables.*	
9. Typhoid		
10. Dysentery and diarrhoea		

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Exercise 1

1. a. Differentiate between communicable diseases and non-communicable diseases.

   b. **Classify the following under** communicable diseases and non-communicable diseases.

   Cold, conjunctivitis, chicken pox, cancer, Coronary heart disease, allergy deficiency diseases, measles,

2. **Name:**

   (i) A viral disease caused by the bite of a mad dog.

   (ii) A bacterial disease transmitted through food and water contaminated by flies.

   (iii) A vaccine that provides immunity against poliomyelitis.

   (iv) A disease caused by a protozoan.

   (v) A disease transmitted by the bite of the Anopheles mosquito.

3. **Match the item in column A with item in column B.**

A		B	
(i)	Sleeping sickness	a.	Scurvy
(ii)	Parasitic in human intestine	b.	Goitre
(iii)	Spread by the *Culex* mosquito	c.	Mongolism
(iv)	Vaccine developed by Louis Pasteur	d.	Tapeworm
(v)	One or both lungs are inflamed	e.	Filaria
(vi)	Deficiency disease	f.	Tsetse fly
(vii)	Hormonal disease	g.	Pneumonia
(viii)	Congenital disease	h.	Rabies
(ix)	Endemic	i.	Athlete's foot
(x)	Fungal disease	j.	Rat
(xi)	Bubonic plague	k.	Spread of disease is rapid and extensive
(xii)	Epidemic	l.	Dsease is specific to a particular region or locality

4. Explain briefly two ways by which infectious diseases spread.

5. **Explain briefly the following terms:**

   (i) Disease (ii) Vaccine (iii) Serum

   (iv) Pathogen (v) Immunisation (vi) Antitoxins

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Importance of Health

A general feeling of well-being can be described as a condition of good health. As such, it is only when a person feels unwell that he seeks medical attention. Yet, a person in apparent good health could be harbouring certain diseases or disorders (like cancer, heart or kidney malfunction) which do not always produce noticeable symptoms at their onset. Therefore, the idea of health must also take into consideration the measures to detect diseases before they acquire serious proportions.

Social or Community Health

Every society must take adequate measures to promote the health of its members. To do so, it must take steps to prevent disease and, if that fails, cure it.

* Curing disease includes building hospitals, clinics; training nurses, doctors; providing financial support to the sick.
* The preventive aspect of social medicine involves the following measures:

1. **Maintaining Food Standards:** Since the risk of infection from contaminated food is high, all stages of food production, storage and processing should be monitored.
   a. Milking herds must be tested every year for the presence of *tuberculosis bacilli.*
   b. Meat must be inspected to exclude tapeworm infestation.
   c. Milk must be pasteurised.
   d. Iodine should be added to salt to combat goitre.
   e. Common food like bread should be enriched with vitamins.
2. **Maintaining Clean Water Supply:** Contamination of drinking water with even tiny amounts of faeces can cause an epidemic of dysentery, cholera or typhoid.
   a. Water must be properly collected, stored, purified and then distributed. Constant tests must be carried out at all stages to ensure that it is not contaminated.
   b. Proper sewers must be provided and linked to sewage treatment plants. This will ensure that the water and sewage do not mix.
3. **Proper Disposal of Sewage and Refuse**
   a. Sewage, and chemical wastes from factories must first be cleaned by chemical treatment before being released into rivers or lakes that are a source of the water supply system.
   b. Unwanted solid refuse can be disposed on land by **incineration.**

Terms to Note

1. **Health:** The World Health Organisation defines health as *"a state of complete physical, mental and social well being and not merely the absence of disease or infirmity".*
2. **Community Health:** Community health can be defined as *"all the personal health along with the environmental services for the importance of health of the community".*
3. **Hygiene:** Hygiene is defined as the science of health and the prevention of disease.

Spread of Infectious Diseases

1. **Insects**
   a. Insects are **'vectors'** or carriers of various diseases. These act as intermediate hosts to pathogens and carry the disease producing bacteria, virus and other parasites to human hosts.
   b. The insects visit garbage, faeces and other excreta and pick up disease germs either on their bristly legs or into their alimentary canal. They then transfer the germs into human food by brushing their legs on exposed food or through their faeces. Flies especially spread the germs by exuding saliva and fluids of the alimentary canal onto the food.
2. **Insanitary conditions**
   a. Insanitary conditions associated with food, water supply and sewage disposal.
   b. Poor personal hygiene associated with dirty skin, hair, nails and personal articles.

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4. **Prevention of food adulteration** and control of harmful insect breeding sites.

5. **Provision of health education to individuals**, groups and organisations; family planning awareness programs; medical care to school students; preventive vaccinations against diseases like tuberculosis, diphtheria, whooping cough, tetanus, measles, hepatitis, etc.

Health Problems of the Third World

The twentieth century has witnessed great improvements in health care in the poorer parts of the world. Immunisation programs spearheaded by international organisations like the **World Health Organisation** (WHO) have eradicated dreaded diseases like **small-pox** and energetic measures against flies, mosquitoes and ticks have brought diseases like malaria, yellow fever and typhus under control.

Symbol of the World Health Organisation

A small-pox victim

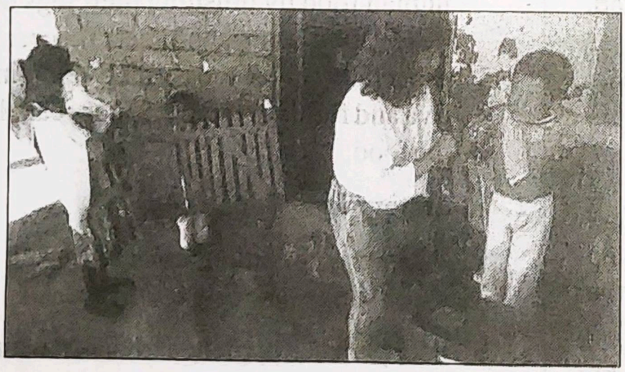
The wasted muscles and protruding bones of these people are almost a badge of the developing countries and a sign of the tremendous problems facing them. These problems are exaggerated by the natural disasters like floods, typhoons and droughts that plague the regions regularly.

Still, much remains to be achieved. Factors that slow down the progress are many:

* The tropical climate of many developing countries encourages the development of the organisms that cause life-threatening infectious diseases.

* Providing and maintaining good health care for a rapidly growing population poses extreme economic burden.

* A population weakened by malnutrition are easy targets for all kinds of diseases.



A child being vaccinated

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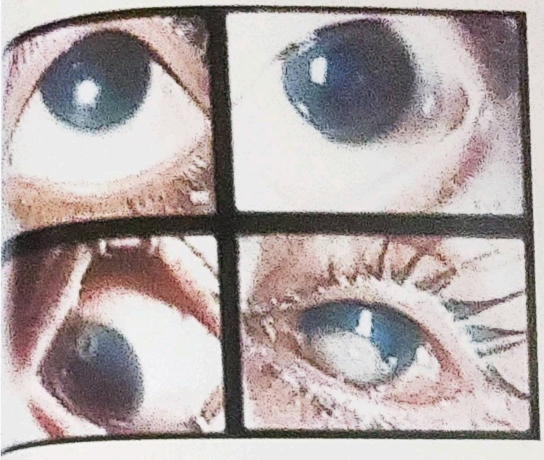
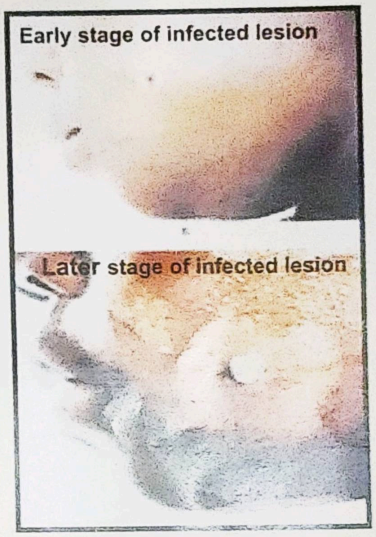
Some Common Human Diseases

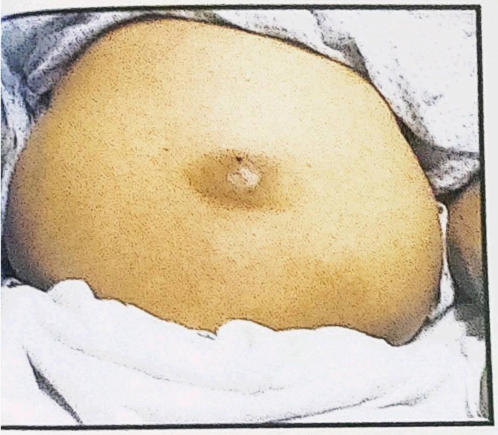


evelopment of ulceration associated with dietary Xerophthalmia

Cutaneous Anthrax :
(Above and right)

Early and advanced stage of infected lesion
The development is rapid and the change is visible within 7 days





Skin (left) and eyes (above) of patients suffering from jaundice

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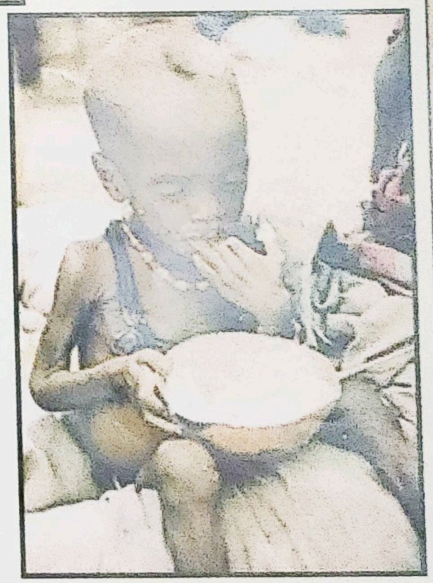
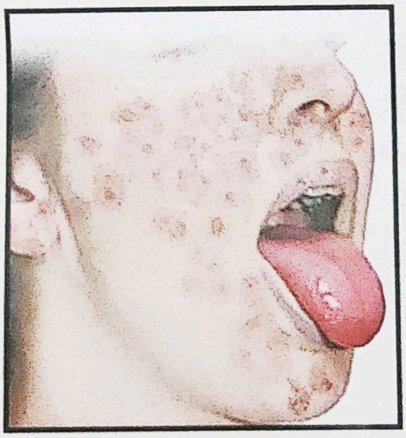


Protein deficiency disease : Marasmus

n inability to absorb niacin (B3) or the mino acid tryptophan may result in ellagra. It is characterised by scaly sores, ucosal changes and mental symptoms.



Pellagra, left and above.

Nails (left) and bleeding gums (right) of a person suffering from scurvy.

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Some Common Human Diseases

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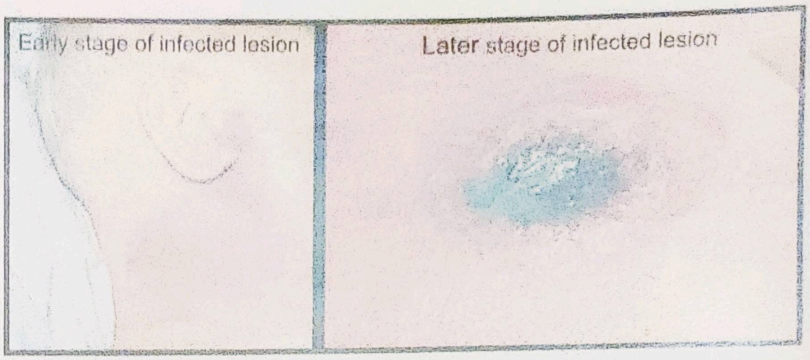

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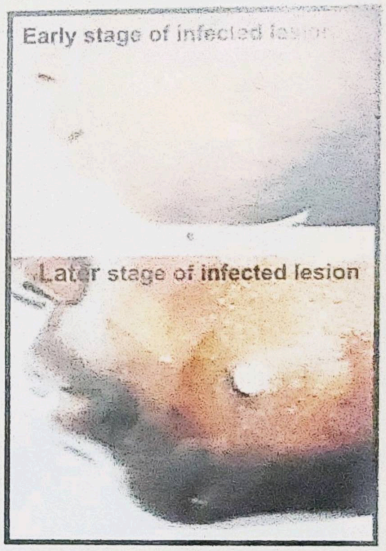

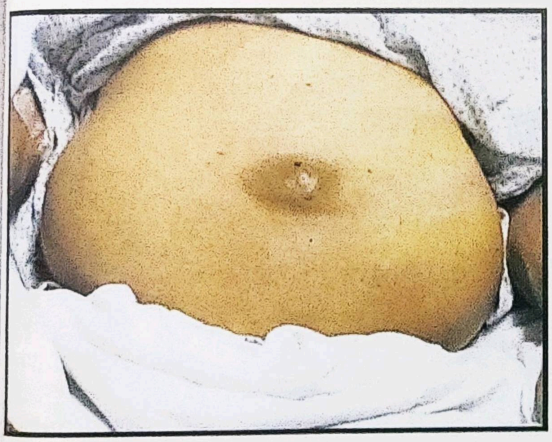

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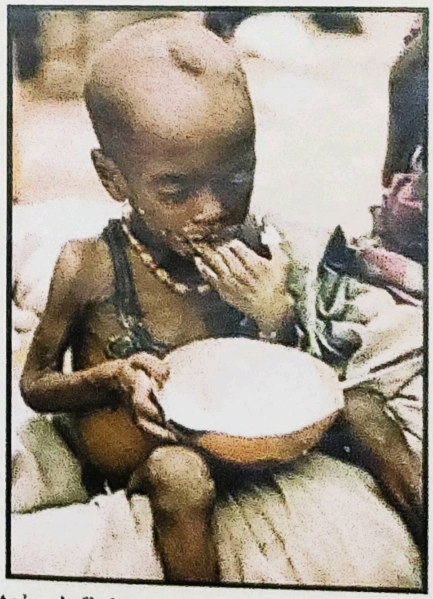

Protein deficiency disease : Marasmus

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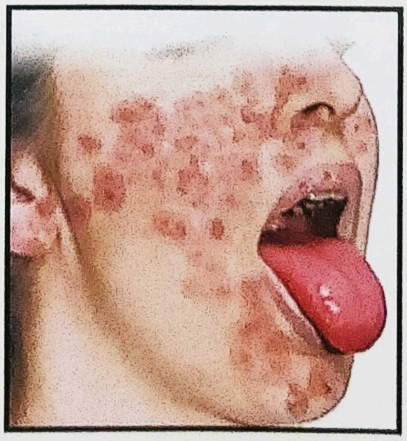
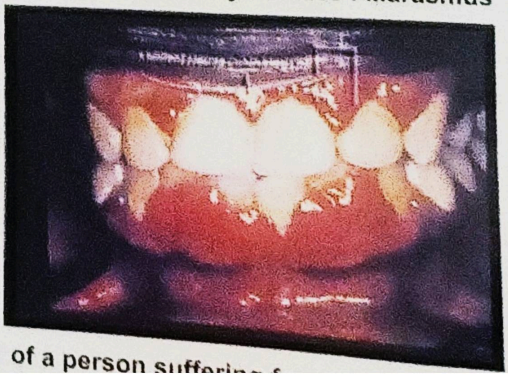


Pellagra, left and above.



Nails (left) and bleeding gums (right) of a person suffering f

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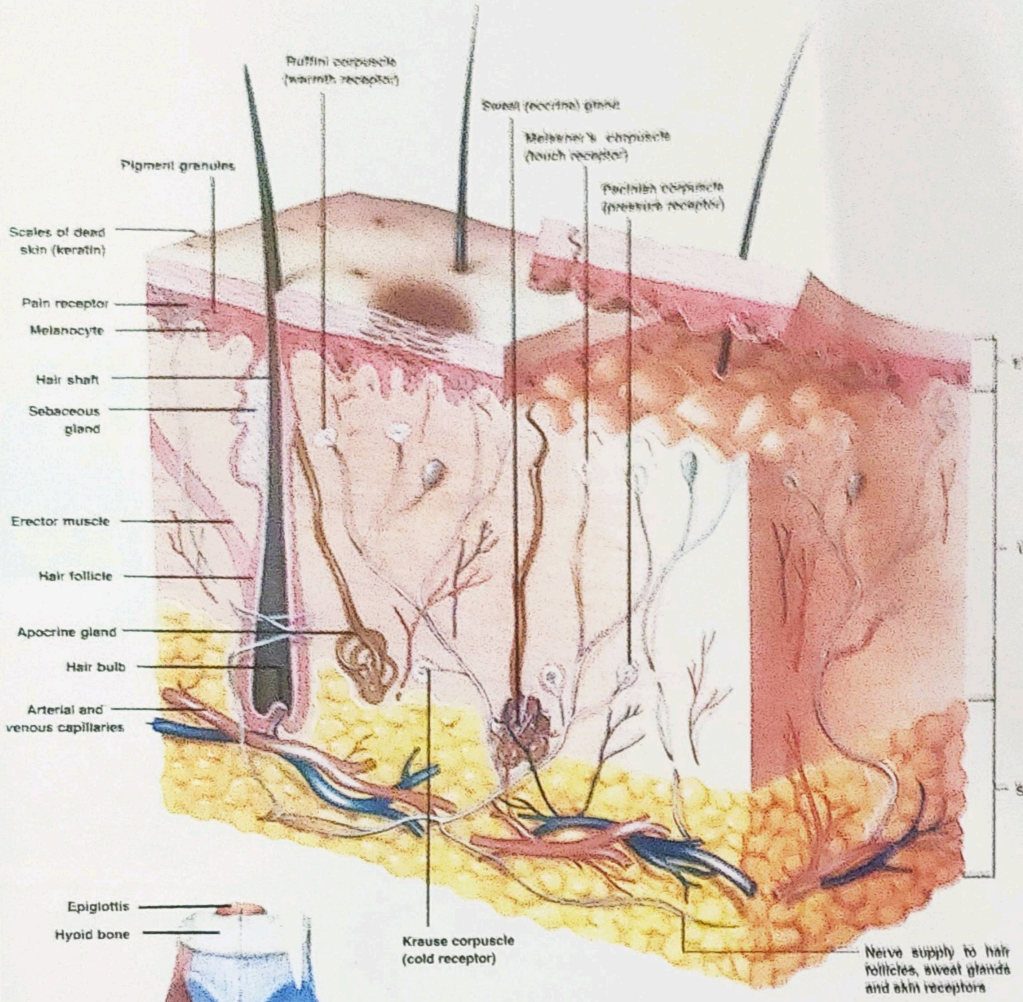
Skin and Lungs



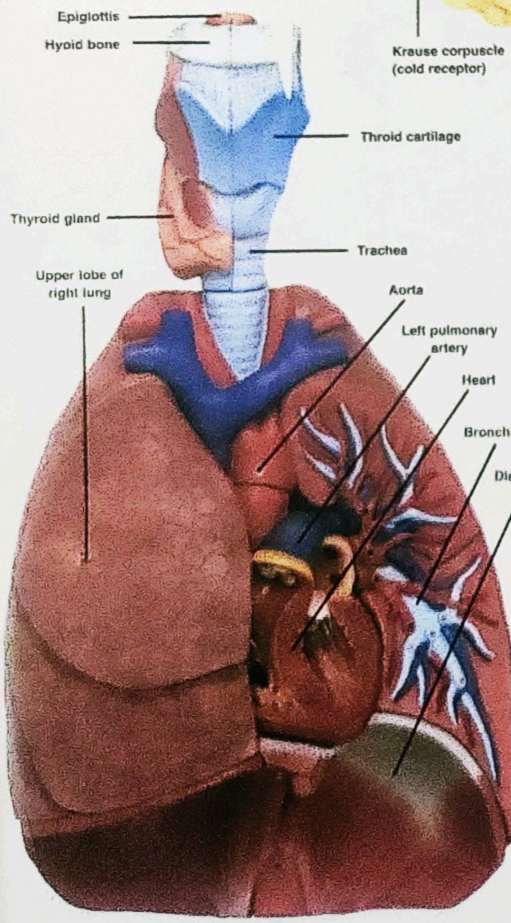
Skin: Sense, Protection, Thermoregulation and Excretion

The skin is the physical barrier between the living body and the outside world. It is made up of two different layers of tissue, the dermis and epidermis.

Both layers contain nerve endings which transmit messages of pain, pressure, heat and cold to the brain.

The protective pigment producing cells (melanocytes) are found in the epidermis. The hair and sweat glands help the body maintain a constant body temperature.

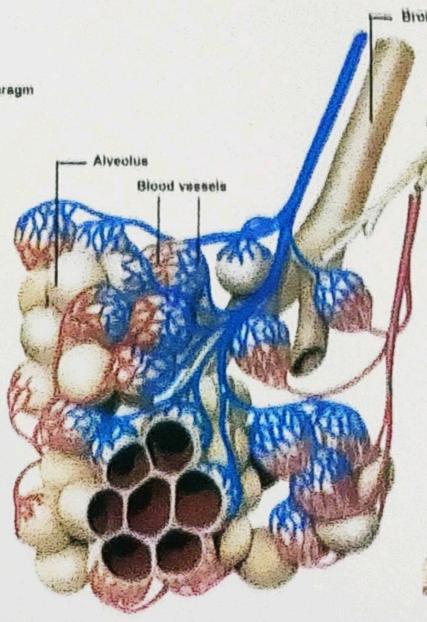
The skin also excretes toxic wastes through sweat.

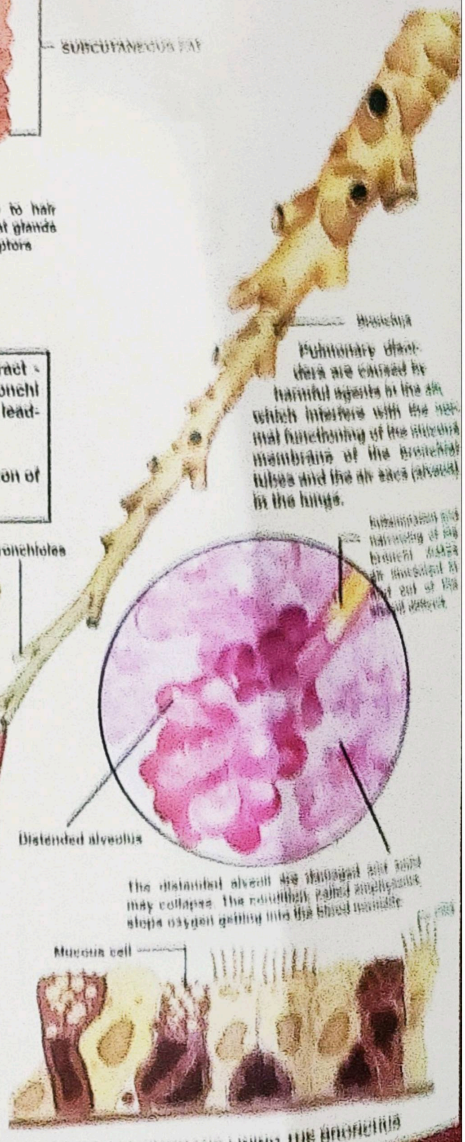


IMPORTANT ORGAN_SYSTEMS OF THE THORACIC REGION

Air enters the body at the upper respiratory tract - nose and trachea. The trachea splits into two bronchi (tubes) which divide into narrower bronchioles, leading into tiny hollow capsules called alveoli.

Air is drawn in and out of this system by the action of the diaphgram and the intercostal muscles.



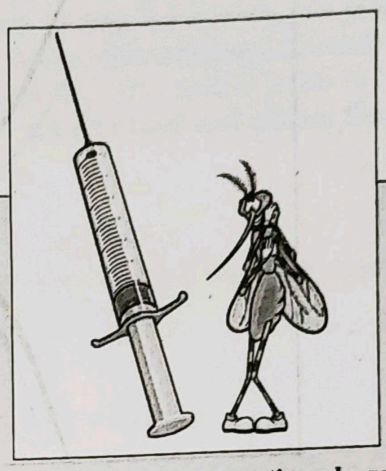


MUCOUS MEMBRANE LINING THE BRONCHUS

Control of Mosquitoes

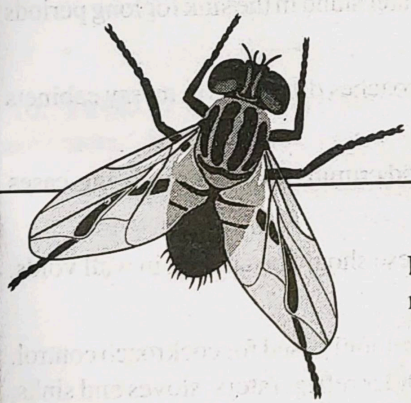
Mosquitoes largely feed on human blood and the female lays eggs in stagnant pools of water. They are nocturnal.

1. **Personal Protection:** Use of mosquito repellants; use of mosquito-net while sleeping; protective clothing that covers the exposed parts of the body, especially after sunset.
2. **Control of Breeding**
   a. **Elimination of breeding places:** Small ponds can be filled with mud. For large ponds and swamps, digging a sloping ditch removes large volumes of water.
   b. **Destruction of Larvae:** Breeding places are sprayed with petroleum oil or insecticides. The oil film on the water surface is toxic to the larva that comes to the surface to breathe air. Insecticides kill the larva and the algae on which they feed.
3. **Control of Adults**
   a. Spraying liquid insecticide like flit or DDT, and fumigation of dwellings with sulphur dioxide.
   b. A mixture of water and 10% DDT in oil sprayed from air kills large numbers of mosquitoes in towns, ponds, marshes and forests.



India is a large country supporting a huge population. Some of the common diseases that afflict a vast majority of her people are malaria, tuberculosis and cholera. These diseases are caused due to unhygienic surroundings which either favour the growth of vectors (disease carriers) or lead to the contamination of food and water by pathogens.

The Government of India has undertaken projects for the eradication of common diseases like malaria, tuberculosis, cholera and leprosy. The programme includes surveys of malaria hit areas, control of mosquitoes by spraying insecticides in their breeding places and distributing anti-malaria drugs to victims.



Control of House flies

Flies feed on garbage, manure and faeces. They also lay eggs on these decaying organic matter. Hence, the control of flies entails the following basic measures.

1. **Protection of Food:** Kitchens should be screened and food must be kept covered.
2. **Control of Breeding of flies**
   a. Garbage should be kept in closed cistern, and then disposed by the municipality by burying or incinerating.
   b. In villages, garbage may be spread out in fields so that it dries up quickly to prevent egg-laying. Lime added to manure also prevents egg-laying.
   c. Garbage and refuse may be treated with insecticides which kill the larvae.
3. **Control of Adult flies**
   a. Spraying houses, barns and stables with DDT.
   b. Wires smeared with a boiled mixture of resin and castor oil (ratio 4:1) can be hung. Flies sit on these wires and die.

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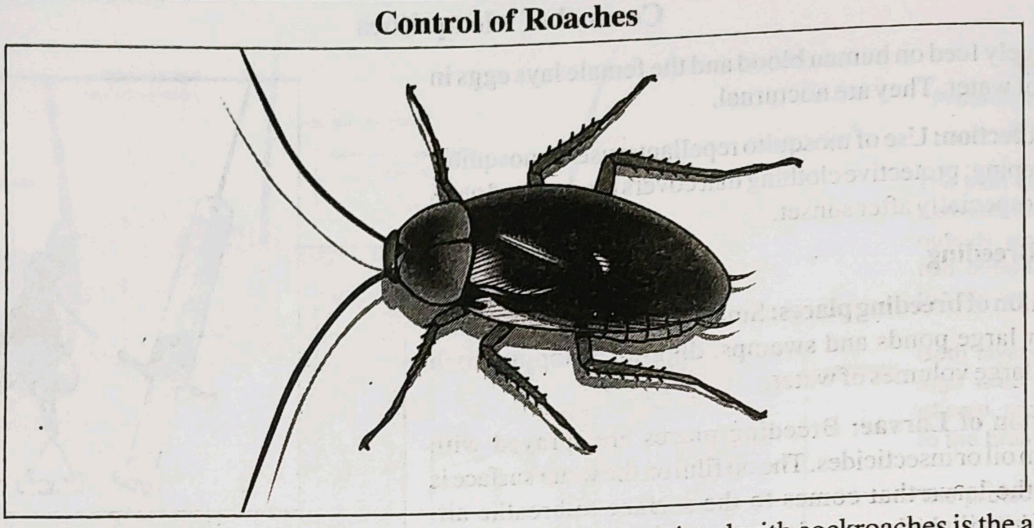
Control of Roaches



While roaches can transfer germs, the most serious medical problem associated with cockroaches is the allergic reaction many people have to their shed skin and droppings. (To grow, all insects must shed their outer skin by moulting).

A. Nonchemical Control: Cockroach control requires a combination of methods. Preventing access to shelter, food and water around the home is one of the best control measures both outside and inside. Good sanitation is important, both inside and outside the house. It is often the best control measure for cockroaches.

* Keep food and garbage in tight containers.
* Clean up all crumbs and spills on floors, counters and shelves as soon as possible.
* Keep faucets and drains under sinks and appliances in good repair. Do not let water stand in the sink for long periods of time.
* Keep clutter from accumulating, especially in kitchens and bathrooms. Cockroaches often hide in messy cabinets and in stacks of newspapers, bags and rags.
* Vacuum often. Vacuuming is very important because it can remove small food crumbs and cockroach egg-cases that may not be killed by insecticides.

B. Chemical Control: Most indoor products come in a dust, bait or spray form. These should be applied in wall voids, cracks and crevices where roaches hide.

* Dusts are slow-acting, but they give long-lasting control. Boric acid is most commonly used for cockroach control. Boric acid should be applied as a thin film in out-of-the-way places such as under refrigerators, stoves and sinks, as well as in wall voids, cracks and crevices. It should not be applied in open areas such as on shelves and counters where food and utensils are kept. Never place in reach of children and pets.
* Baits usually come in plastic stations or in a gel tube. Some of the commonly used insecticides in baits include hydramethylnon, sulfluramid and avermectin.
* Sprays in either liquid or aerosol form generally provide the quickest control of cockroaches. Insecticides commonly used in indoor sprays include allethrin, diazinon, chlorpyrifos, hydroprene, permethrin, pyrethrins and resmethrin. Never spray into or around electrical outlets. Some exposed surfaces where cockroaches crawl can be treated, but food preparation and eating areas should be avoided. Some sprays may damage carpets, tile or plastics.

Outdoors, homeowner products for cockroach control are mostly limited to liquid sprays. Just as indoors, the spray should be applied to cracks and crevices where cockroaches are suspected of living or entering the home. A perimeter treatment along the base of the foundation wall can also help control the larger outdoor cockroaches. Large-scale insecticide applications are best applied by a professional pest control applicator.

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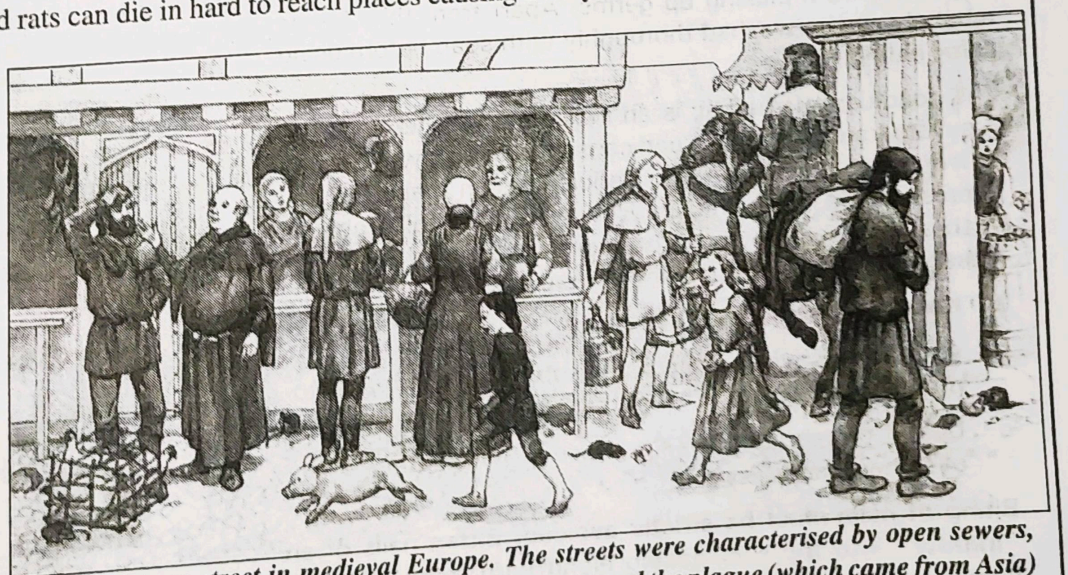
Control of Rats

Rats infest our neighbourhood and home in search of food. They are attracted to foods, fats, oils that have been spilled and left on counters, floors, appliances and tables; Grains, like cereal, oats, rice and vegetables like potatoes and carrots that are in cardboard boxes and plastic bags; Pet food in boxes or bags. Any garbage that is not in a can with a tight lid. Therefore, to keep rats out: **do not give food and shelter them.**

1. Birdhouses and seed should be on poles and in trays rats can not get.
2. Keep garbage can lids closed tightly.
3. Roof rats get into your house from tree branches that hang over the roof. Keep trees cut back and plant bushes so they will stay at least 3 feet from your house.
4. Keep yards and alleys clean.
5. Do not compost any animal products (fish, meat, chicken, cheese, butter). Keep lids tight.
6. Use only rodent resistant composters.
7. In basements keep any food in closed containers that rats can not chew through.
8. Cover all openings to your house. Rats can get into very small places.
9. Rats live in sewers and can follow the food in pipes up to the toilet. Therefore,
   * Keep your kitchen sink rinsed clean and use garbage disposals as little as possible.
   * Rinse out your kitchen sink once or twice a month. Use 1 cup of bleach or of baking soda followed by 1 cup of vinegar and rinse with boiling water.
   * Never throw grease down the drain.
   * Keep your toilet lid down when not in use.
10. **To kill a rat, use a rat trap.** The best trap is the large, simple, cheap wooden **"snap trap."** They are sold in hardware stores. Make sure the trap is safe from people, children, pets or animals who could get hurt from it.
    * **POISONS ARE NOT RECOMMENDED** for rat control, because children or other animals may eat it by mistake. Also, poisoned rats can die in hard to reach places causing a very bad smell.
    * **DEAD RATS** must first be wrapped in newspaper, *or* placed in a plastic bag before putting it in a tightly covered garbage can. Injured or sick rats *must be killed,* then wrapped and put in the garbage can.
    * **Wash your hands with hot water and soap after getting rid of dead rats !** (even if you used gloves)



A typical town street in medieval Europe. The streets were characterised by open sewers, litter, rats and refuse. The unhygienic conditions caused the plague (which came from Asia) to spread and kill nearly 25% of the population.

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Personal Hygiene

Hygiene is defined as the science of health and the prevention of disease.

While a clean surrounding reduces the risk of infection and disease, a clean, healthy and well nourished body further ensures that diseases are kept at bay. Hence, proper care and attention must be given to our **skin, nails** and **hair,** since these, being the body's outer covering, are most susceptible to infection. Other body parts, such as the **eye, ear, nose** and **mouth,** deserve as much attention since these are the ports of entry for germs.

1. Care of the Skin

The skin is the body's first line of defence against infection. A clean, intact skin is a barrier to bacteria and fungi. Regular bathing with a mild soap keeps the skin free of **dirt, grease** and **foul body odour.** If the skin is not washed regularly, the hair follicles get blocked with dirt. As such, the sebum accumulates and the skin becomes easy target to infection since sebum is nutritive to certain bacteria.

Action of Soap

Soap dries out the skin, and strips it of its protective sebum. Strong soaps can even cause allergic reactions like itching and soreness. Hence, a mild soap is recommended.

Body Odour

Stale perspiration gives rise to body odour. In order to prevent body odour:

1. Bathe and shower daily.
2. Wear fresh garments everyday.
3. Use underarm deodorants and anti-perspirants. Deodorants kill bacteria that collect in the arm-pits.

2. Care of Hands and Nails

Hand is the tool that enables us to perform all manual tasks. It therefore, has to cope with a great deal of rough treatment.

Thus, while doing work like gardening or laundary, in which the hand faces the threat of infection from the soil, or is subjected to chemical irritants like detergents, hands can be protected by wearing gloves. This also protects the fingernails from picking up germs. Apart from this, hands must always be washed thoroughly with soap before using it for eating.

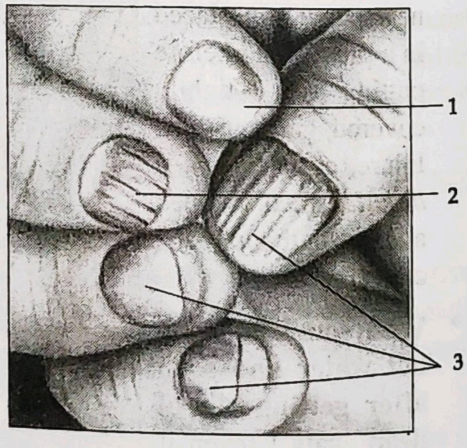
The condition of the nail is an indicator of general health. A severe traumatic illness can cause the nail growth to slow down temporarily while iron deficiency can make the nail depressed and moon-shaped. However, most nail problems such as split edges and brittleness are caused by abuse rather than dietary deficiency. Therefore,

a. Keep nails short and well filed.

b. Avoid any obvious irritants or submersion in water for prolonged periods.

c. Use of protective gloves and use of hand lotion whenever necessary.

Biting of nails must be strictly avoided. Bitten nails often **"ingrow"** into the skin, taking along with them infective bacteria. The same bacteria gain entry if the cuticle is destroyed.



Some common problems of the nail associated with (1) congenital abnormality, (2) calcium deficiency, (3) bitten nails .

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3. Care of the Hair

Two of the most widespread problems associated with hair that can be effectively checked by proper hygiene, are that of **dandruff** and **lice.**

* Dandruff is usually a mild form of eczema in which scales of dead skin flake from the scalp. The best treatment for dandruff is regular washing with a shampoo containing **selenium** compounds or coal tar extracts. If the problem is severe, a doctor must be consulted.

* Lice lay their eggs on the shafts of hair, and the young lice that hatch out cause intense itching. They can be killed by washing the hair with shampoos containing **lindane.**

A general point to note is that combs and hair brushes must never be shared, even among family members. Moreover, they should be washed with soap at least once a week.

4. Care of the Teeth and Gums

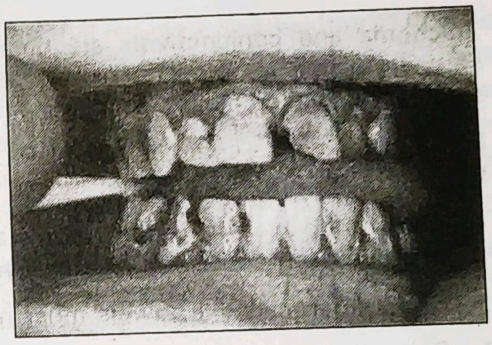
Common problems of the teeth include **dental caries** (tooth decay) and **bleeding gums.** In most cases bad breath arises from these basic disorders. Both these conditions can be easily prevented by following the simple rules of dental hygiene.

* The teeth and gums must be cleaned thoroughly after every meal, or at least twice a day. Regular brushing with a fluoride tooth-paste, flossing and massaging the gums are effective ways to prevent decay and disease.

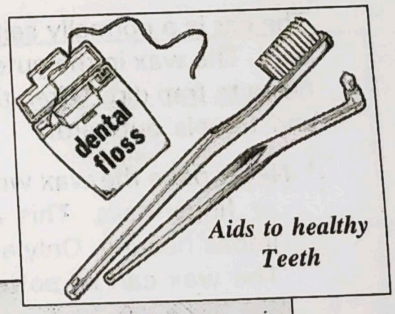
* Intake of sugary items should be reduced. In fact sweets in between meals should be strictly avoided. This is because during meals it is possible for the saliva to repair the small amount of damage caused by the interaction of sugar and bacteria in the mouth. If the teeth are constantly bathed in a sugar solution, this repair process cannot occur.

* On a large scale, tooth decay can be prevented by adding fluorine to water supplies. Fluorine prevents tooth decay, both during the development of teeth and after they have erupted.

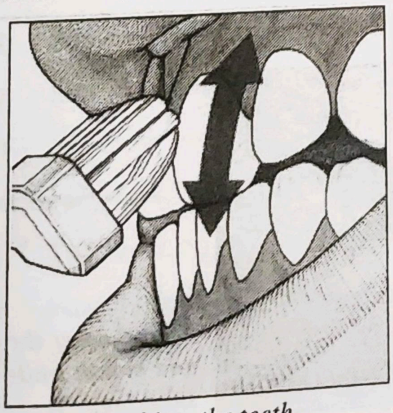
The infection and inflammation that follows gum disorders are caused by bacteria. If untreated, this leads to loss of bone around the teeth, which finally loosen and fall out.



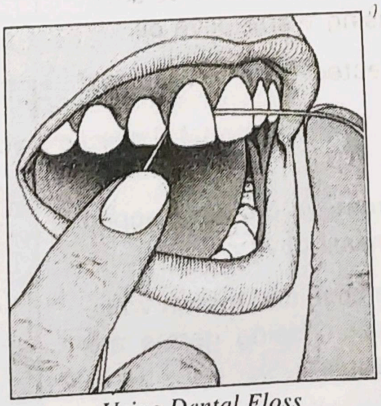
Tooth decay (caries) results in the wearing away of the tooth enamel leaving the inner soft dentine dark and disfigured.



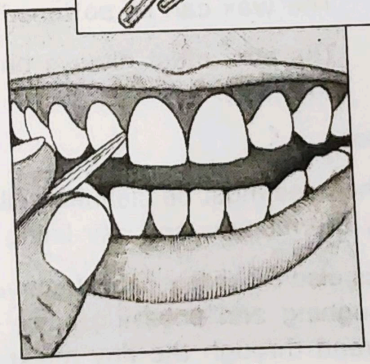
Aids to healthy Teeth



Brushing the teeth



Using Dental Floss



Massaging the Gums

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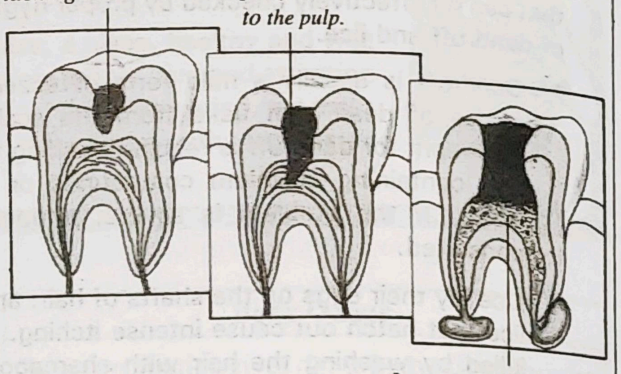
Role of Dental Plaque in Tooth decay and Gum disease

Tooth decay: The teeth is covered by a gelatinous bacteria and food-laden layer called dental **plaque.** The decay or caries begins with the breakdown of carbohydrate food-stuffs caught in the plaque by bacteria normally present in the mouth.

In the presence of sugar, the bacteria produce acid which dissolves a hole through the protective enamel surface. Once the enamel is penetrated, destruction of tooth decay is rapid.

Gum disease: The plaque collects around the gum margin, inflames the gums and eventually loosens the contact between the teeth and gums. The gum shrinks away from the tooth, leaving a gap in which the bacteria breed.



5. Care of the Eyes, Ear and the Nose

Eye

Trachoma and **conjunctivitis** are common eye problems spread through contamination by hand and personal articles like handkerchiefs and towels.

Eye strain is also a common complaint. Therefore, care of the eyes include the following:

* Bathing the eyes daily with warm water to which a little salt has been added, or with an eyewash.
* Personal articles like towels must not be shared.
* Protection of eyes from the glare of the Sun.
* Provision of adequate lighting while reading and writing.
* Avoid excessive viewing of television.

Working on a computer screen can make the eyes feel tired. This is because muscles concerned with focussing are subjected to a heavy workload.

Ideally, you should work at a screen for 20-minute stretches with a five-minute between each and do something completely different after two or three hours.

Have your eyes tested if you have problems with tired, red or itchy eyes, or with headaches.

Ear

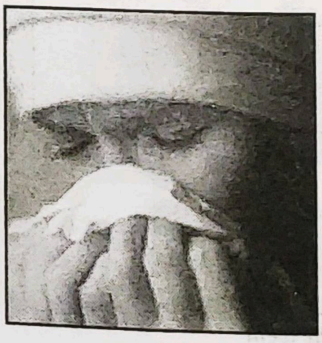
The ear is a normally self-cleaning organ that requires little care. The wax in the outer ear contains a bactericide which helps to trap dirt. Often the wax melts due to body warmth and travels outward.

* Never poke the wax with any pointed object like hair-pins or finger-nails. This could damage the ear-drum and impair hearing. Only a soft, moist swab should be used. The wax can be softened by using warm olive oil.
* The ears must always be protected from severe cold and heat.

Nose

The nose must be cleaned daily to remove the dirt trapped by the mucous and hair lining the nasal cavity.

It is also a healthy habit to cover the nose and mouth while coughing and sneezing since disease-causing germs are spread through the tiny moisture droplets.



Always cover the nose and mouth while sneezing.

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6. Rest and Exercise

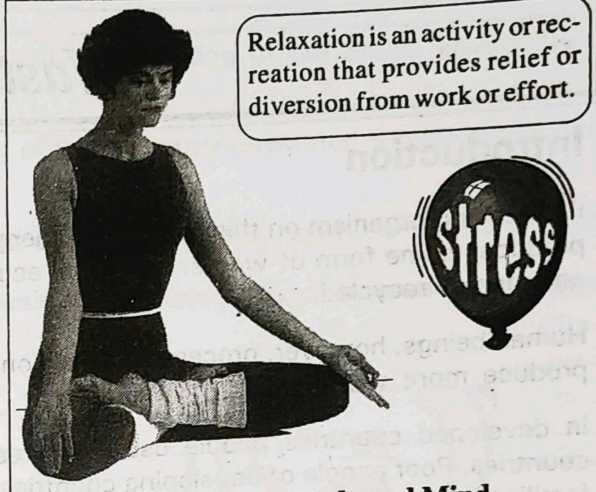
The various organs of the body are continually working to carry out the several physiological and metabolic needs of the body. As such the body has two vital requirements to keep it in a fit condition.

a. **Rest:** The body must get sufficient rest. This is possible through adequate sleep. The sleep pattern and duration varies with age and nature of work. For example, infants sleep for almost 14 to 20 hours while a normal adult requires about 6 to 8 hours of sleep. The **quality of sleep** (deep/relaxed) and **leisure activities** also contribute towards a healthy mental state.

b. **Exercise:** In order to keep the muscles well toned and active, exercise is a must. Exercise not only makes you look and feel your best, but there is impressive evidence that people who exercise regularly and correctly are less prone to heart attacks, strokes and other life-threatening conditions.

Deserving as much importance as personal hygiene is a **balanced** and **nourishing diet.** It is necessary for proper growth, development and maintenance of our body. Proper nutrition should also be accompanied by correct food habits. Care must be taken to ensure the following:

* Vegetables are washed thoroughly before cooking. Hands should also be washed before handling food-stuff.
* Food is fresh and protected against dust, flies, and cock-roaches.
* Food is stored and served in clean utensils.
* Meals are taken at fixed intervals.
* Overeating is avoided. Addictive items like tobacco and alcohol are also avoided.



Relaxation is an activity or recreation that provides relief or diversion from work or effort.

Relaxing the Body and Mind

The idea that people are as healthy as they feel arises from the fact that physical illness and mental health are closely linked. For example, coronary thrombosis (heart attack) is clearly related to a stressful life-style and is often precipitated by a worrying event.

Yoga and meditation are recommended highly as a measure to relax the body and mind.

Exercise 2

1. **Explain briefly:**
   (i) We should cover our mouth and nose while coughing or sneezing.
   (ii) The skin must be kept clean.
   (iii) Biting of nails must be strictly avoided.
   (iv) Eating sweets in between meals should be avoided.
   (v) We must wash our hand thoroughly before using it for eating food.
2. **List three ways:**
   (i) The breeding of flies can be controlled.
   (ii) Healthy food standards can be maintained.
   (iii) The eyes can be protected from infection.
   (iv) Body odour can be prevented.

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16
Waste Generation

Introduction

Every living organism on this Earth uses energy to utilise and process raw materials and in doing so, it often produces some form of waste. In natural eco-systems, such wastes are soon used up by other organisms and hence recycled.

Human beings, however, process materials on a large scale using enormous quantities of resources and thus, produce more waste.

In developed countries people use more resources and produce more waste than those in developing countries. Poor people of developing countries make use of as much waste material as possible. Often whole families of poor people make a living by collecting, sorting and recycling rubbish. Today all human beings have become aware of waste and many industries are recycling more materials. Cars are being manufactured with recyclable parts, garbage segregation is being done on a large scale, vermiculture, composting and organic manure from biodegradable waste is being made, many industries are using recycled materials, etc. Yet we are still buying more and more new goods rather than re-using or repairing the old goods and thus, we are accumulating waste.

What happens to the waste or rubbish that we throw away? Metal cans, glass pieces take a lifetime to break down and disappear. Plastic can survive for hundreds of thousands of years. We need to think and dispose of these materials in a more responsible way.

Reducing wastes will help solve problems of energy, pollution, refuse disposal. Along with the government, we individuals can do more to encourage waste saving and thus, help to preserve and conserve our environment.

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Sources of Waste

Waste is any material that is no longer useful and is discarded. According to the British Environment Protection Act (1990), waste is defined as under:

1. Any substance which constitutes a scrap material or an effluent or other unwanted surplus substance arising from the operation of any process and
2. Any substance or article, which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled.

Depending on their source, wastes are broadly classified as

1. **Household or domestic waste:**

   Waste substances produced in households is termed as domestic waste. Leftover food, fruits, vegetables, waste paper, plastic bags, metal cans, glass pieces, cloth pieces, discarded old clothes, discarded batteries, medicines, chemicals, sewage from toilets, exhaust gases from cooking stoves, etc. are all examples of different kinds of household wastes.

Domestic Waste

2. **Municipal waste:**

   These are wastes that include household waste as well as wastes from restaurants, public places, institutions, markets, street sweepings, shops, banks, hospitals, etc.

   Basically municipal waste includes all the garbage, rubbish, ashes (due to burning of coal, wood, etc.) demolition and construction waste, dead animals, etc. Municipal waste is collected from large dustbins kept in different parts of a city.

Municipal Waste

3. **Industrial waste:**

   Industries whether small or big produce wastes that include rubbish, ashes, construction and demolition wastes, toxic wastes, etc. Waste matter produced by industries maybe solid, semi-solid, liquid or gaseous.

   A lot of waste produced by factories is injurious and **hazardous** to health of all living organisms including humans. As industries use a lot of fuel, they give out harmful gases like sulphur dioxide, nitrogen dioxide, etc.

   Liquid effluents releases by industries into the water bodies such as harmful chemicals, pesticides, etc., are very toxic.

Industrial Waste

4. **Agricultural waste:**

   These wastes are produced by intensive agriculture and crop production. They include mainly wood waste, crop residues, molasses, tobacco waste, pesticides, fertilisers, etc.

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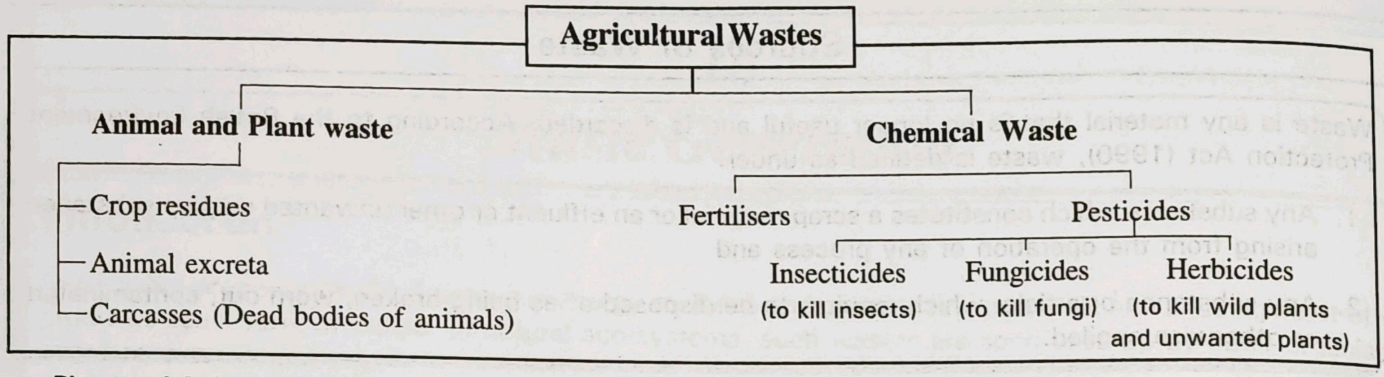


Plant and Animal waste:

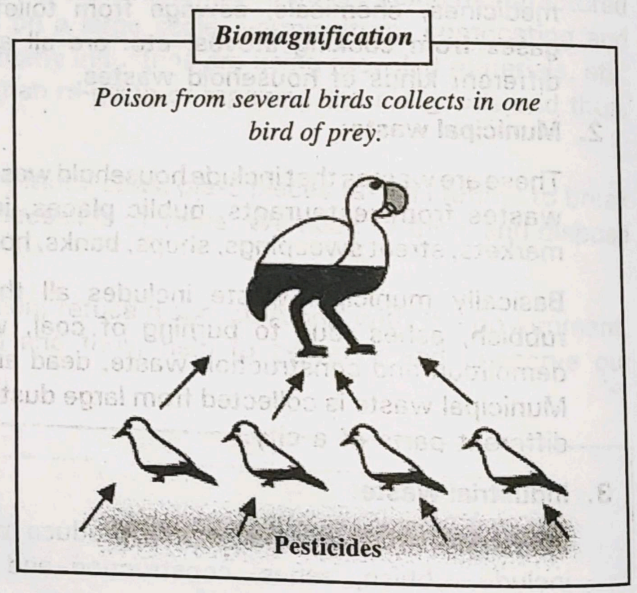
These consist of crop residues (seeds, molasses, bagasse, etc.,) which are usually left behind after the crop is harvested, and animal excreta or waste produced by animals). Most of these wastes are biodegradable and can be turned into manure or used to produce energy (biogas). But if these wastes, especially animal excreta, enter the water bodies then they can cause the spread of many water borne diseases.

Fertilisers and Pesticides:

Fertilisers are chemical compounds, usually of nitrogen, phosphorus and potassium, that are added to the soil to increase crop production. Sometimes these fertilisers are washed away in surface runoff of water, reach the water bodies and enter the food chain. This results in **biomagnification.**

Pesticides and insecticides are also **toxic chemicals** that are used to eliminate insect pests that harm crop plants. Often these harmful chemicals enter water bodies and cause great harm to aquatic life.

Pesticides when sprayed on crops can also be blown by the wind to other areas. They can also seep through the soil and contaminate ground water.



5. Bio-medical waste:

This consists of syringes, needles, and plastic bottles, contaminated and used bandages and swabs, laboratory wastes like blood samples, urine samples, etc., generated in hospitals, clinics and bio-technological research laboratories. By-products of surgical operations such as tissues, organs, limbs, tumors, etc., also are a part of this waste.

6. Radioactive waste:

These are harmful chemicals that are the most dangerous as they can remain harmful for thousands of years. These are generated from X-ray machines in hospitals and airports.

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Nuclear reactors and nuclear power stations also release radioactive substances into the environment. Radioactive waste can be classified as:

(i) Low level waste:

These substances decay quickly as they are low in radioactivity.

Example: Contaminated articles like equipment and clothing from hospitals and nuclear power plants.

(ii) Intermediate level waste:

These are the containers used to carry the radioactive materials, equipment and radioactive sludge produced by the nuclear power plant.

Example: Fuel rods and liquid waste from power plants.

(iii) High level waste:

This is the most dangerous as it consists of discarded radioactive substances. These often take thousands of years to decay

7. Commercial waste:

The waste derived from buildings, shops, stores, offices, markets, hotels, garages, etc. It consists of waste from construction or demolition of buildings that includes dirt, stones, concrete, bricks, plaster, wood, electrical wiring, etc.

Hotel wastes consists of dishes, paper, plastic glasses, used metal cans, soft drink bottles, etc. Waste from shops, offices, stores includes paper, plastic, stationery articles, old furniture, cloth, etc.

E-Waste

This is a recent phenomenon also known as Electronic Waste. Computers are very useful in offices, schools, hospitals, etc. But after use, the computer becomes obsolete and together with its keyboard, monitor and central processing unit, etc. it is discarded as E-waste. As such, there is no scientific method of recycling computers, hence IT companies (Information and Technology) keep discarding old computers which are piling up as scrap material.

New technological advancement in computer science produces new computers and the market gets flooded with new computers and old ones are discarded, adding to the waste.

Few industries and the waste produced by them are given in the table below.

Industry	Waste Produced
1. Paper	Wood chips, fibres often mixed with lime.
2. Petrochemical	Oil, grease, gases like H_2S, SO_2, sulphur compounds.
3. Metal Processing	Ash, scrubber wastes, metal hydroxide sludge, gases like SO_2, CO, etc.
4. Thermal Power Plants	Coal, dust, and fly ash
5. Plastic and rubber industry	Latex, bits of plastic
6. Dyes and pigments	Sludge of raw materials, harmful chemicals
7. Pharmaceuticals	Raw material solids, biological wastes
8. Food processing	Waste products and remains of dairies, breweries, meat-processing units, foul smelling gases, disease causing organisms.
9. Textile	Effluents from boiling of fibres
10. Nuclear reactors	Radioactive substances

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Properties of Waste

The waste substances produced by the various sources can be broadly classified on the basis of their properties. Accordingly they may be **biodegradable and non-biodegradable waste, toxic or hazardous, non-toxic waste, inflammable,** or **carcinogenic.**

1. **Bio-degradable:**

   These pollutants are **organic matters** which decompose by the activity of microorganisms. Therefore, the pollution in such cases is negligible.

   However, when these substances occur in large quantities such that the microorganisms are unable to decompose them fully, they pollute the environment.

2. **Non-biodegradable:**

   Some substances like **aluminium, iron, lead, mercury, salts, phenolic compounds** and **pesticides** like **DDT,** etc., do not decompose, or even if they do, they decompose very slowly. These substances, therefore, accumulate in the atmosphere and reach the body of living organism through the food chain and cause tremendous harm.

3. **Hazardous: Toxic, Inflammable and Carcinogenic Wastes:**

   Hazardous waste is a type of waste which can cause serious health problems in human beings and serious harm to the environment when it is stored, transported or disposed of. Hazardous wastes include toxic or poisonous waste.

   Typical hazardous waste includes **radioactive substances, poisonous chemicals, heavy metals** (arsenic, lead, mercury, etc.) **biological wastes, flammable substances, explosives,** etc. Sources of hazardous wastes are **industries, nuclear power plants, hospitals, research laboratories, etc.**

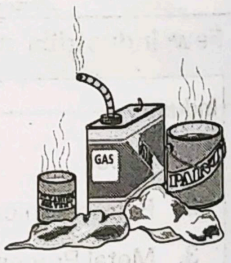
   When buried in the ground or left in open dumps, some hazardous waste can pollute groundwater and contaminate food crops.

4. **Non-Toxic Wastes:**

   These are the vegetable and fruit peels, paper, etc. that are usually thrown in dustbins. These wastes are generally biodegradable. They do not directly cause harm to the environment but if the accumulation of this type of waste is large, decay will take longer and then it can pose problems.

Biodegradable Waste	Non-Biodegradable Waste
1. Can be broken down to simple non-poisonous substances by the action of microorganisms in nature.	Cannot be broken down to simple non-poisonous substances by the action of micro-organisms in nature.
2. Can be recycled naturally and/or by humans. Their products do not pollute the environment.	Cannot be recycled naturally. Their products cause pollution.
3. Can produce useful products after biodegradation.	They remain unchanged chemically because they are not biodegradable.
4. Do not disturb the ecological balance in nature.	They disturb the ecological balance in nature.
5. **Example:** Paper, cattle - dung	**Example:** DDT, synthetic fibres, metals

Hazardous Waste



A waste is said to be hazardous if it is flammable, corrosive, highly reactive, toxic (poisonous) and reacts strongly with water. Chemicals can be termed as hazardous if they lead to the following health problems in human beings.

1. Causes cancer: Radioactive substances are carcinogenic
2. Toxins affect the reproductive system, the nervous system, respiratory system, and cause damage to eyes and skin. For example,
   (i) Pesticides decrease sperm count.
   (ii) Mercury causes nerve damage.
   (iii) Sulphur dioxide and nitrogen dioxide affect the lungs.

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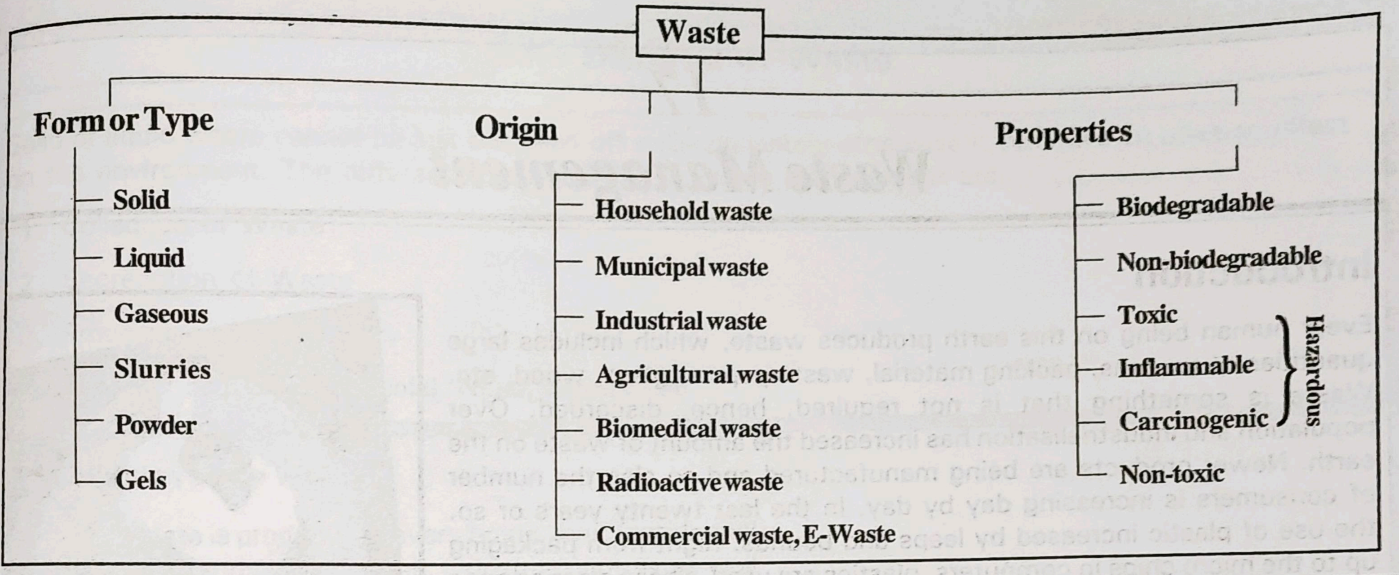

Exercise

1. What is waste? How does it originate?
2. List the types of wastes based on origin.
3. a. List out five types of waste materials generated in urban households.
   b. Suggest ways to minimise the waste generation and to convert waste materials into eco-friendly products.
4. What is medical waste?
5. Differentiate between biodegradable and non-biodegradable waste. Give examples.
6. List three hazardous wastes and explain the effect of these wastes on human health.
7. Classify the following substances as toxic and non-toxic wastes.

   (i) Cow dung (ii) Cardboard packets (iii) Plastic
   (iv) Computer mouse (v) Injection syringe (vi) Bandages
   (vii) Thermacol pieces (viii) Paints (ix) Plaster of Paris Statues
   (x) Banana peels
8. Explain how untreated industrial waste can be hazardous to health.
9. Explain how chemical agricultural waste is hazardous to the environment.
10. Name the wastes produced by the following industries:

    (i) Thermal Power Plants (ii) Plastic and Rubber Industry (iii) Pharmaceuticals
    (iv) Food Processing Industry (v) Textile Industry (vi) Petrochemical Industry
11. What is E-waste? How is it generated?
12. How are radioactive wastes generated?
13. Many countries have passed laws banning the use of plastic bags. Plastic bags have been now been replaced by paper bags for carrying groceries and other such items. Give a reason for this.

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2. Segregation of the Waste

One of the most important steps in waste management is the segregation of solid waste into different categories. According to the category, the method of disposal or recycling is carried out.

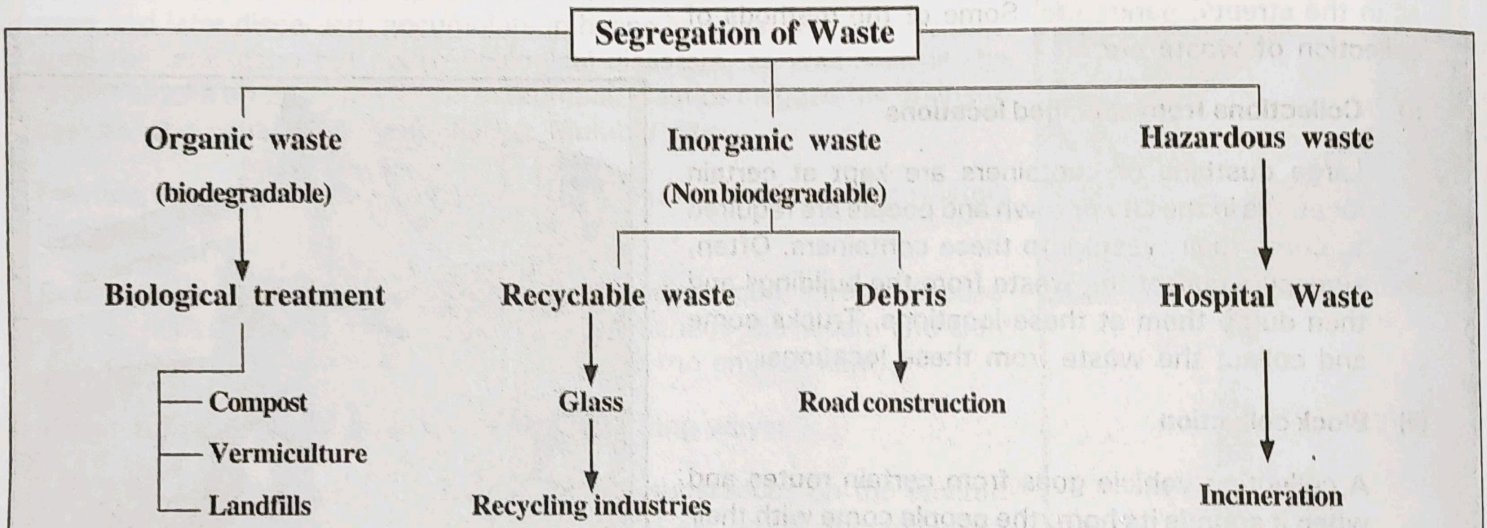
Example:

Biodegradable waste such as food scraps, vegetables and fruit peels, etc., can be turned into manure and non-biodegradable waste like metal, glass, plastics can be recycled.

The most effective way would be to segregate the waste at the source only. **'Dry waste'** and **'wet waste'** should be kept in separate bins.

Wet waste: Organic waste like vegetable, fruit peels, food substances, etc.

Dry waste: Recyclable material like metal, glass, plastics, etc.



Hospital waste should be further categorised as:

(i) Infectious : Containing waste from surgeries, etc., can have disease-causing bacteria. Even disposable needles, syringes, blades, broken glass, etc., can be infectious.

(ii) Pathological : Tissues, body parts, human flesh, foetuses, blood samples, etc.

(iii) Pharmaceuticals : Outdated medicines, contaminated drugs and chemicals, etc.

(iv) Radioactive : Solid, liquid or gaseous waste contaminated with radioactive substances that have been used in the treatment of various diseases.

(v) Hospital linen, bed sheets, utensils, etc.: All these may be contaminated with infectious germs.

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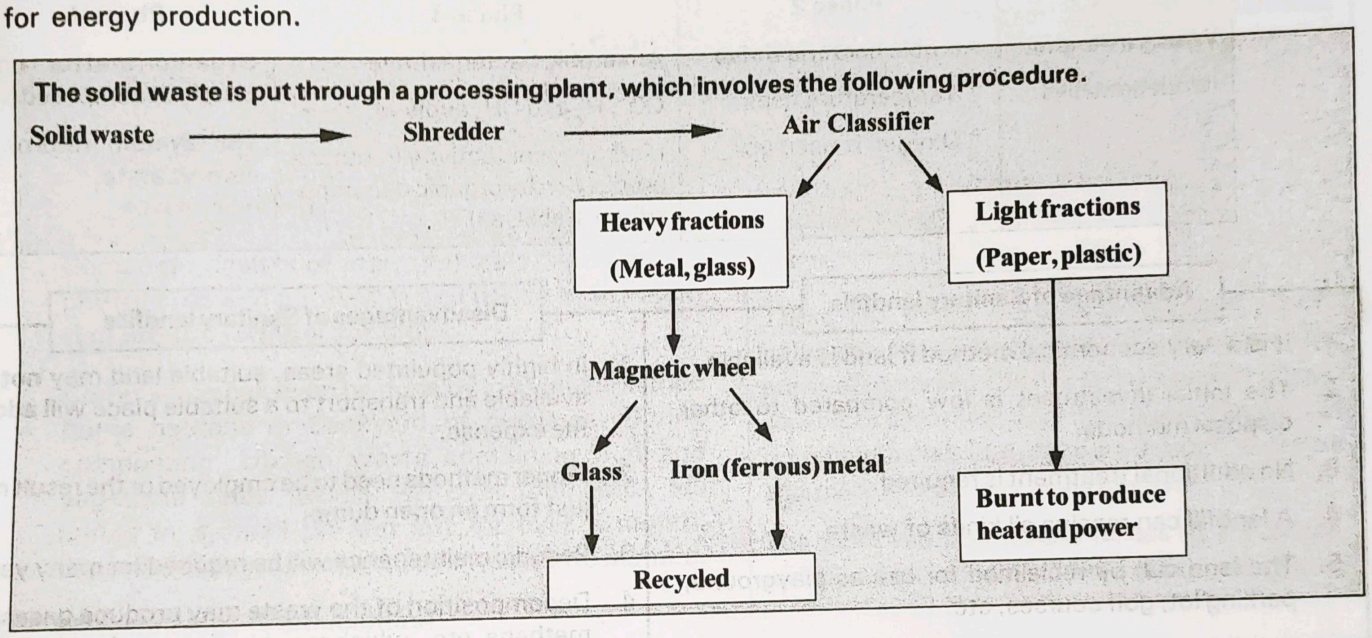
3. Processing and Recovery of Waste

Most of the components of solid waste may be valuable as a source of raw materials for industry, for production of fuel, etc. Hence, processing the solid waste helps to recover materials that can be put to further use.

Processing the solid waste helps to recover large proportions of glass, paper, metal, plastics and wood. Metal and glass as well as plastic are recycled whereas the other lighter portions of paper and wood are used for energy production.



4. Disposal of the Waste

The solid wastes which are of no further use usually consist of residues left after solid wastes have been processed and products have been recovered or energy produced from them. These residues have to be disposed off in an eco-friendly manner, particularly hazardous waste and bio-medical waste.

Solid Waste Disposal Methods

A. Sanitary landfills
B. Incineration
C. Composting
D. Biotechnology (vermiculture)
E. Production of bio-gas

Common methods of Disposal of Solid Waste

A. Sanitary landfills

The solid wastes are dumped into low-lying areas on the land and covered with good earth of at least 20 cm thickness. This ensures that **insects and rodents do not enter the landfill** and the **refuse is not directly exposed.** Each layer is then left for at least 7 days and it is compacted by bulldozers. Insecticides are sprayed on top to prevent breeding of mosquitoes and flies.

Steps involved in Landfills

Depositing the waste
↓
Compacting it by bulldozers
↓
Covering it with 20 cm of soil

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The solid wastes eventually stabilise and within 2 to 12 months the waste settles down by 20% to 40% of its original height.

For the first few years there may be some odour but after that the land can be used for developing parks, etc.

The waste deposited in a landfill undergoes biological decomposition in the following phases:

Type of vegetation over the landfill should be such that:

1. Plants should be drought resistant.
2. Plants should be such that the roots do not penetrate more than 30 cm.
3. Plants should be such that they have the ability to thrive in low nutrients. They should be of a hardy variety.

Phase 1	Phase 2	Phase 3	Phase 4
Waste in landfill (biodegradable)	Aerobic bacteria thrive * Temperature rises * Oxygen is used up	Anaerobic bacteria thrive CO_2, H_2 and CH_4 evolved Methanogenic activity (methane production by organic decomposition) stabilises.	Organic matter completely decomposed The system returns to aerobic state.

Advantage of Sanitary landfills

1. It is a very economical method if land is available.
2. The initial investment is low compared to other disposal methods.
3. No additional treatment is required.
4. A landfill can receive all kinds of waste.
5. The land can be reclaimed for use as playground, parking lot, golf courses, etc.

Disadvantages of Sanitary landfills

1. In highly populated areas, suitable land may not be available and transport to a suitable place will add to the expense.
2. Proper methods need to be employed or the result may just form an open dump.
3. Periodic maintenance will be required for many years.
4. Decomposition of the waste may produce gases like methane, etc., which may become a nuisance.

B. Incineration (Burning)

Combustible and non-combustible materials from the solid waste are separated so as to reduce the load on the furnace. Combustible components of garbage, rubbish and dead animals are burnt. The minimum temperature in the incineration plant should be around **670°C** to incinerate all the organic matter and oxidise all the foul smelling gases.

However, the bye-products of incineration are toxic ash and certain gaseous products. Burning of plastics produces toxic substances like **dioxins.** Hence, before burning, the waste should be properly segregated.

Ashes are generally dispersed by dumping them in low-lying areas while the solid, residual particles can be used for road construction.

Points to Note

Incineration means burning of the solid waste in proper furnaces.

* By burning the waste, the volume of the waste is reduced by 20% to 30% of its original volume.
* This method is generally used when land is not available for dumping and disposal into the oceans or seas is not possible.
* Incineration is a very important method of disposing bio-medical waste as many infectious organisms are killed.
* Pollution due to incineration is less and very often the heat generated is used to produce electricity.

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C. Composting

Composting is a process by which bacterial decomposition of the organic fraction of solid wastes is carried out. The end product left after bacterial decomposition is called **humus.**

Decomposition of the organic matter can be done by aerobic or anaerobic bacteria depending on the amount of oxygen available. By bacterial decomposition,

(i) The **volume of the waste gets reduced considerably**

(ii) **Pathogens (disease causing organisms) are destroyed** and the compost or humus can be safely handled.

Compost consists of many minerals like nitrogen, phosphorus and potassium and hence is an important **natural fertiliser** for crops.

Composting can even be done by individuals in their home gardens or backyard of buildings. During composting, kitchen waste containing fruit and vegetable peels, leaves, left over food, etc., are buried in a small pit and left for over a month. Bacterial decay converts all this waste into **manure.**

Importance of Compost

1. It provides nutrients to the soil, as it is rich in nitrogen, phosphorus and potassium.
2. It improves the waste holding capacity of the soil.
3. It provides trace elements like copper, molybdenum, manganese, magnesium, etc.
4. It helps to bind the soil and reduces soil erosion.

Pollution Sinks

These are living organisms that can absorb pollutants. For example, water lilies can restore the purity of rivers and other water bodies. The plant is capable of absorbing huge quantities of heavy and poisonous metals like cadmium through its leaves and roots without any adverse effect.

The plant can also absorb metals like mercury, nickel, cobalt as high as 16% of its dry weight.

D. Biotechnology (Vermiculture)

Natural decomposition by aerobic bacteria soon depletes the oxygen and anaerobic bacteria start thriving. This slows down the decay of organic waste and emits foul smelling gases.

The earthworm's gut provides an ideal breeding home for aerobic bacteria. As the worm ingests the soil, the bacteria in its gut decompose the organic content of the soil and the soil that is then excreted through the anus of the earthworm becomes manure, known as **"vermicastings"**.

* Vermicastings are a highly enriched biofertiliser, which contain a large number of microbes. The burrowing action of the earthworm also aerates the soil.
* Vermicastings also contain hundreds of tiny earthworm cocoons, which hatch within a month and add to the earthworm population already in the soil.

Importance of Vermiculture

The degradation of organic wastes by earthworm consumption is called vermiculture.

Vermiculture or vermicomposting is **eco-friendly, less expensive** and **beneficial** in the long run.

The most useful feature of this technique is that it **combines soil processing with waste processing.** When biodegradable wastes are applied to a soil containing earthworms in the form of mulch, the decay starts almost immediately.

Earthworms can thus be used very effectively to restore the fertility of degraded soils as well as process organic wastes.

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E. Production of Biogas (Biomethanation)

In this method organic wastes like vegetable matter, crop residues and animal waste like cow dung are decomposed by bacteria in the absence of air (anaerobic) to produce bio-gas which contains 70% of methane gas. This gas can then be used for cooking, lighting street lamps, producing electricity, etc.

The **slurry** (solid residue) left after decomposition can be used as **manure.**

Points to Note

1. The formation of bio-gas is a **biological process.**
2. Bio-gas is obtained by the **anaerobic fermentation** of animal waste. Fermentation takes place in the **absence of air,** but in the **presence of water.**
3. Bio-gas is a mixture of **methane, carbon dioxide and hydrogen** along with **hydrogen sulphide** (H_2S) and water vapour in traces. Chief constituent of bio-gas is methane and it constitutes about **70%** of the gas. **Methane (CH_4)** is a very **good fuel.**
4. A small village can use its own rubbish and sewage to produce bio-gas. Animal dung is collected in tanks and fermented. Some of the waste is converted into liquid which soon starts to give off methane. The gas, stored in tanks with expandable lid, is used in homes for **cooking** and **heating.**

Disposal of Liquid Waste

Liquid wastes that are produced on a large scale are responsible for the pollution of water bodies like lakes, rivers and seas. These wastes may be liquid or semi-solid.

Eutrophication and **bio-magnification** are some of the outcome of discharging untreated liquid wastes into the water bodies. Not only is aquatic life destroyed but also toxins reach human beings through the food chain. Thus, it becomes absolutely necessary that sewage and other industrial effluents be properly treated, rendered harmless and then released into the water for disposal.

Types of Liquid Wastes

1. Sewage
2. Industrial Effluents
3. Agricultural Effluents
4. Waste from Nuclear Power Plants

Different sources of Waste water

1. **Domestic wastes** : These arise from sinks, toilets, washing machines, etc., which contains solids, organic matter, dissolved gases like ammonia, some metals, etc.
2. **Industrial wastes** : Water contains suspended particles or dissolved substances often metals, toxic organic compounds and acids.
3. **Surface drainage** : It consists of water from pavements, car parks, roads, etc., and contains metals, organic compounds and bacteria.
4. **Agricultural runoff** : These consist of runoff of water from fields that contains bacteria, nutrients and organic matter as well as fertilisers and pesticides.

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Effluent Treatment

Effluents that are discharged from industries contain both organic and inorganic substances. Hence, the treatment is done in such a way that 'useful waste' can be recovered at the same time.

The method involves three basic steps:

1. **Primary Treatment:** Large, floating solids are removed, for example, wood, plastic, by gravity settlement and screening.
2. **Secondary Treatment:** Organic matter, like **sewage sludge**, is removed by oxidation or by precipitation. Chemical coagulants like potash alum are sometimes added to quicken the sedimentation process.
3. **Tertiary Treatment:** This tertiary treatment is used when the effluent is being used for irrigation or for recycling. The water is passed through clear quartz tubes that are exposed to intense **ultra violet light. All pathogens are thus fully destroyed.**

Nitrate and phosphate levels are further reduced in the tertiary treatment to prevent eutrophication when the water is released into the water bodies.

Note: Secondary treatment serves two purposes:

1. Oxidises organic compounds to carbon dioxide, etc. Due to oxidation of the organic compounds many odours are eliminated. Pathogens are greatly reduced thus making the water less infectious.
2. Converts the remaining organic matter to solids, which can settle down.

Purification of Water for Consumption

The steps involved are:

1. **Aeration** : Unwanted gases are removed by bubbling air through the water.
2. **Removal of Hardness** : By addition of lime and soda ash (sodium carbonate) soluble calcium and magnesium salts are removed as precipitates.
3. **Settling Tanks and Filtration** : Suspended and heavy particles are removed.
4. **Sterilization** : 1.49 of chlorine is added per cm^3 of water to kill germs.

Drainage

Drainage systems are designed to remove surface or sub-surface water from residential, industrial or agricultural areas. The main principle behind any drainage system is to provide an open, suitable, readily accessible channel into which surface water or excessive water from the soil can readily flow.

Drains and channels help to remove excess water from marshes; wetlands and land, which suffers, frequent flooding. Proper drainage systems help to prevent soil erosion also.

Note

The floods experienced in Mumbai on July 26, 2005 were partly due to clogged drains. Garbage and rubbish should not be indiscriminately thrown on the roads or drains. If the drains are blocked, the water cannot drain away and this causes flooding.

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Small-scale drainage is carried out on agricultural lands by farmers to remove surface water from fields.

For large-scale drainage it is better to improve the natural stream channels so that large amounts of water can be drained away without causing any damage.

* In order to drain flat lands, a main drain is laid on one side of the plot and a number of transverse drains are connected to it.

  These lateral drains are made parallel to the main drain and eventually join the main drain at the lower end of the field.

* In cities and towns a proper drainage system consists of drains running parallel to the roads and these drains eventually join underground drains beneath the roads.

  The underground drains then open into water bodies like rivers, lakes, etc.

Did you Know?

The time taken for different wastes to rot

1.	Waste food	3-4 weeks
2.	Paper bags	1 month
3.	Cloth bags	5 months
4.	Wood pieces	10-15 years
5.	Leather	40-50 years
6.	Iron sheets	50-100 years
7.	Aluminium sheets	200 years
8.	Plastic bags	1 million years

Proper drainage in fields helps in the following ways:

a. Prevents soil erosion

b. Prevents excessive accumulation of water-soluble salts.

Proper drainage in cities helps in the following ways:

a. Prevents flooding during monsoons.

b. A clean hygienic environmrnt is maintained.

Drainage in Cities and Towns

In cities and towns there are two systems of drainage: The **storm water drainage system** (SWD) and the **waste water (sanitary) drainage system.**

1. **Storm-water drainage System:**

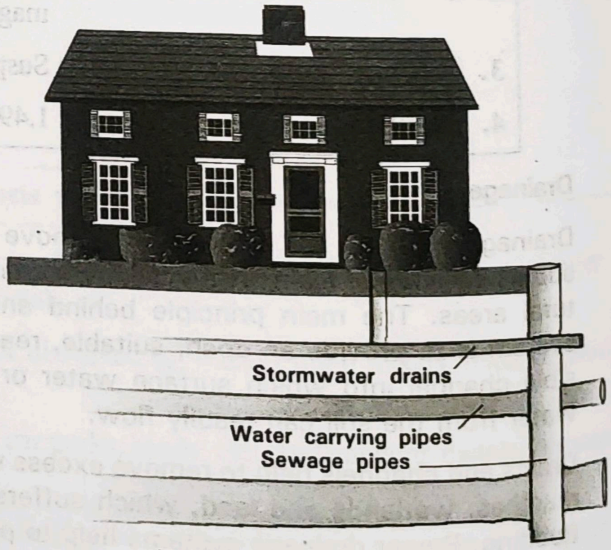
   This consists of a network of structures, channels and underground pipes that carry storm water or rain water to ponds, lakes, streams, rivers or wetlands.

   Inlets to these channels are located at the curbs, yards or open pipes near roads, homes and industries.

2. **Sanitary or Storm sewer System:**

   This consists of pipes that carry water and waste from drains connected to sinks, bathtubs, showers, toilets, etc. to a treatment plant to be treated and filtered. It is a closed pipe system accessible through man holes.

   Storm-water does not flow to a treatment plant.



Drainage in Cities and Towns

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Disposal of Bio-medical Waste

Bio-medical waste consists of the waste generated from hospitals, clinics, dispensaries, veterinary institutions, pathological laboratories, blood banks, etc., during diagnosis, treatment or research of human and animal diseases This waste can be is solid or liquid form.

The best way to dispose of bio-medical waste is by **incineration** and **burial**. Liquid bio-medical waste can be disinfected and then discharged into drains. After incineration, the waste can be sent to land fills. The following table shows some of the different categories of biomedical wastes and the treatment:

Biomedical wastes usually contain:

* **Heavy metals** like mercury, chemicals, preservatives (e.g. formalin), most of which are carcinogenic (cancer causing).
* **Plastics**, which when burnt, produce harmful chemicals called **dioxins** and other pollutants that are harmful for human health, and a threat to the environment.

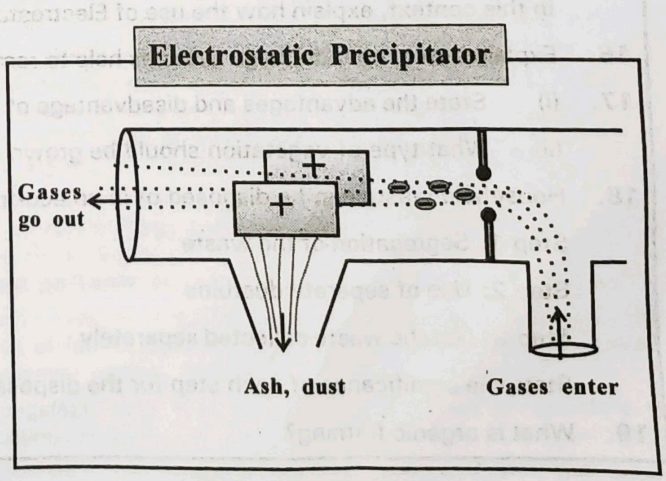
Category	Treatment
1. Human anatomical waste	Incineration and burial
2. Animal Waste	Incineration and burial
3. Biotechnological waste	Incineration
4. Discarded medicines	Incineration and disposal in land fills
5. Solid waste from blood and body fluids	Incineration and autoclaving
6. Disposable item – syringes, tubes, etc.	Disinfection, shredding
7. Liquid waste	Disinfection by chemicals and discharge into drains
8. Chemical waste	Discharge into drains and if solid then into landfills

Methods to manage Air Pollutants

Air pollutants generally consist of effluent gases from industries. These gases usually contain particulate matter such as dust particles, unburned carbon particles, fumes or mist. Two commonly used devices to remove particulate emissions are the **Electrostatic Precipitator and the Wet Scrubber**

a. Electrostatic Precipitator (ESP)

This is the most efficient device for removing particles. The incoming waste gases are passed over high voltage electrodes, giving the particles an electric charge (negative charge). Then these particles pass between positively charged collector plates, which attract the negatively charged particles and thus remove them. Such devices are attached to the chimneys of coal-burning power stations to remove ash particles. More than 99% of the ash is removed by these electrostatic precipitators.



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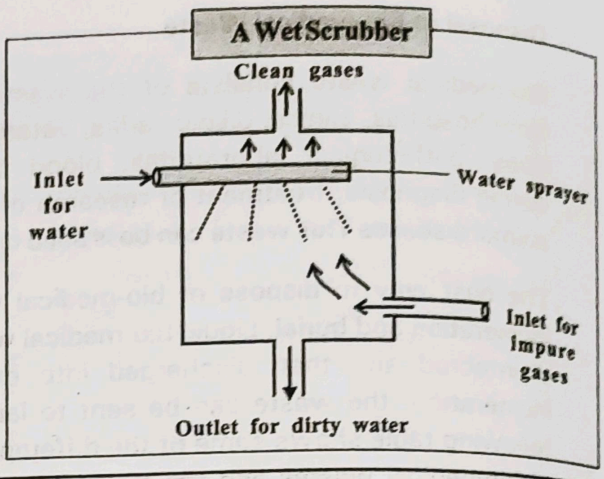
b. Wet scrubbers

The exhaust gases pass into a chamber where these is a spray of water. The water settles on the dust particles and thus they settle down.

Wet scrubbers also remove water-soluble gases like sulphur dioxide, nitrogen dioxide, hydrogen suphide, ammonia, etc. However, the water that comes out contains dissolved gases and particulate matter and often causes pollution.

Sometimes wet lime powder is also sprayed into the hot exhaust chamber to neutralise the acidic gases.



Exercise

1. What is waste management? How does it help?
2. Why is segregation of waste important before disposal?
3. What are the different steps involved in waste management?
4. What are sanitary landfills?
5. a. What is incineration?
   b. What type of waste should be incinerated?
6. What are the bye-products of incineration? How are they disposed off?
7. What is composting? State its advantages.
8. What is vermiculture?
9. "Of all the animals, few have contributed so much to the development of the world, as we know it as earthworm" Charles Darwin. With reference to this statement discuss the use of earthworms in biotechnology.
10. A biogas plant solves the fuel as well as environmental problems. Discuss.
11. List the different sources of wastewater.
12. What is a pollution sink? Explain with an example.
13. Give two methods to reduce the amount of solid waste generated by urban households.
14. List out five types of waste materials generated in urban households. Suggest ways to minimize the waste generation and to convert waste materials into eco-friendly products.
15. "A considerable proportion of dust from industrial sources has its origin in bad housekeeping".
    In this context, explain how the use of Electrostatic precipitator and wet scrubbers can help.
16. Explain how proper drainage systems help to remove surface or sub-surface water.
17. (i) State the advantages and disadvantage of Sanitary landfills.
    (ii) What type of vegetation should be grown on a landfill site?
18. Household waste can be disposed of in an eco-friendly manner by following the steps given below:
    Step 1: Segregation of the waste
    Step 2: Use of separate dustbins
    Step 3: Get the waste collected separately
    State the significance of each step for the disposal of household waste.
19. What is organic farming?

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Abdomen: Part of the body that lies below the thorax.

Acetabulum: Cup-shaped cavity in the hipbone into which the head of the thigh-bone fits.

Acetylcholine: A neurotransmitter.

Acne: Inflammatory disease of sebaceous glands, characterised by pimples on the face, neck. Common in adolescents.

Acropetal: Developing upwards towards the apex from the base.

ADP: Adenosine diphosphate, an organic compound that is formed when ATP undergoes hydrolysis of the terminal phosphate bond and releases its energy.

Adrenal gland: Two small dissimilarly shaped endocrine glands, one located above each kidney, consisting of the cortex, which secretes corticosteroid hormones, and the medulla, which secretes adrenaline. Also called "suprarenal gland".

Adrenaline: A secretion of the adrenal glands causing acceleration of the heart, constriction of small blood vessels, dilation of the pupils, and an increase in metabolic rate.

Aerobe: An organism, (e.g., bacterium), requiring air to live.

Aestivation: A state of dormancy during the summer or periods of drought.

Afferent: Nerves that conduct impulses from the periphery of the body inwards to the brain or spinal cord.

AIDS (Acquired Immune Deficiency Syndrome): An abnormal condition of the body's immune system, in which the body's defences against disease are permanently weakened.

Air bladder: An air-filled structure in many fishes, which helps to maintain buoyancy or aids in respiration.

Albinism: Absence of normal pigmentation in a person, animal, or plant.

Albumin: Water-soluble proteins found in egg white, blood serum, milk, various animal tissues and plant juices and tissues.

Aleurone: A protein forming the outermost layer of endosperm in cereal grains.

Algae: Primitive, aquatic plants that lack true stems, roots, and leaves but contain chlorophyll.

Alimentary canal: Mucous lined tube of the digestive system, extending from the mouth to the anus. Includes the oesophagus, stomach and intestines.

Alkaloid: Nitrogen-containing organic bases derived from plants. Including nicotine, quinine, cocaine, atropine and morphine.

Allergy: Excessive sensitivity to some environmental factor or substance, such as pollens, particular foods, dust, or microorganisms, causing an adverse physical reaction.

Alveolar: A section of the jaw containing the tooth sockets; A type of connective tissue in animals.

Alveolus: An air sac of the lungs, at the end of a bronchiole, through which exchange of respiratory gases takes place.

Alzheimer's disease: A degenerative disease of the brain, often occurring in middle age, causing progressive loss of mental faculties.

Amoeba: Protozoa occurring in water, soil, and as internal animal parasites. Has indefinite, changeable form and moves by means of pseudopodia.

Amoebic dysentery: An infectious, inflammatory disease of the colon, caused by *Entamoeba histolytica.* Results in severe pain and diarrhoea.

Amoeboid: Resembling an amoeba, especially in changeable form and means of locomotion.

Amphibian: Cold-blooded, smooth-skinned, vertebrates of the class Amphibia (frog, toad, salamander). Hatch as aquatic larvae that breathe by gills and metamorphose into adult having lungs.

Ampicillin: An antibiotic given orally or by injection to treat a variety of infections of the urinary, respiratory, and intestinal tracts.

Amylase: Any enzyme that converts starch or glycogen to sugar.

Amylopsin: Starch-digesting amylase produced by the pancreas.

Anabolism: The metabolic process by which simple substances are synthesized into the complex materials of living tissue; constructive metabolism.

Anaemia: Deficiency in the oxygen-carrying pigment haemoglobin or in the number of red blood cells. Symptoms include pallor, tiredness and breathlessness.

Anaerobe: A microorganism (e.g., bacterium), able to live in the absence of free oxygen.

Anaerobic: Respiration that does not require free oxygen.

Anal fin: An unpaired fin in fishes, located on the ventral median line between the tail and the anus.

Anatomy: The structure of a plant or animal, or of any of its parts.

Androecium: The stamens of a flower considered collectively.

Angiosperm: A plant characterised by having seeds enclosed in an ovary; a flowering plant.

Animal kingdom: The category of living organisms that include all animals.

Animal: Organism of the kingdom Animalia, characterised by power of locomotion, fixed structure, limited growth, non-rigid cell walls, specialised sense organs and rapid response to stimuli, and non-photosynthetic metabolism.

Annual: Living and growing for only one year or season.

Anopheles: Mosquitoes of the genus *Anopheles.* Many carry the malaria parasite and transmit the disease to humans by their bite.

Ant-eater: Mammals that lack teeth and feed on ants and termites.

Antenna: One of the paired, flexible, jointed sensory appendages on the head of an insect, myriapod, or crustacean.

Anther: Male reproductive part of flower. Forms the upper end of a stamen. Produces and discharges pollen.

Anthocyanin: Water-soluble pigments, found in certain plants. Impart red, purple, or blue colouring to flowers, fruits, and autumn leaves.

Anthrax: An infectious, often fatal disease of warm-blooded animals, especially of cattle and sheep, caused by the bacterium *Bacillus anthracis.* It is transmissible to man, capable of affecting various organs, and especially characterised by malignant ulcers.

Antibiotic: Substances, such as penicillin and streptomycin, produced by certain fungi, bacteria, and similar organisms. Inhibits the growth of, or destroys microorganisms. Widely used in the prevention and treatment of diseases.

Antibody: Proteins in the blood that are generated in reaction to the invasion of foreign substances, which they neutralise, thus producing immunity against infections.

Anticoagulant: Any substance that suppresses or counteracts coagulation, especially of the blood.

Antigen: Any substance that when introduced into the body, stimulates the production of an antibody.

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Antiperistalsis: Contractions of the alimentary canal that push food back towards the mouth.

Antitoxin: An antibody formed in response to, and capable of neutralising a poison of biological origin.

Anuresis: Inability to urinate.

Anuria: Failure of the kidneys to produce urine.

Anus: The excretory opening at the end of the alimentary canal.

Aorta: The main trunk of the systemic arteries, carrying oxygenated blood from the left side of the heart to the arteries of all limbs and organs except the lungs.

Aortic arch: The section of the aorta that passes over the top of the heart and back down to the fourth thoracic vertebra.

Apetalous: Having no petals.

Apocarpous: Having distinctly separated carpels.

Areola: A small dark coloured area around a centre portion, as about a nipple or part of the iris of the eye.

Arteriosclerosis: Chronic disease in which thickening and hardening of arterial walls interferes with blood circulation.

Arthritis: Inflammation of joint/joints, producing pain and stiffness.

Arthropod: Invertebrate organisms of the phylum Arthropoda, (e.g., insects, crustaceans, arachnids, millipedes and centipedes), having a horny, segmented external covering and jointed limbs.

Artificial respiration: Method of restoring or initiating normal breathing in an asphyxiated but living person, usually by rhythmic forcing of air into and out of the lungs by mouth-to-mouth breathing or manual pressure on the chest.

Ascorbic acid: A white, crystalline vitamin, found in citrus fruits, tomatoes, potatoes, and leafy green vegetables. It is used to prevent scurvy. Also called "vitamin C".

Asexual: Characterising reproduction involving a single individual, without male or female gametes, as in binary fission or budding.

Aspergillus: A type of fungus.

Assimilation: The process by which molecules of digested food are incorporated into living tissue; constructive metabolism.

ATP: Adenosine-triphosphate, a nucleotide, occurring in plant and animal cells is a major energy source for vital processes. Energy is released when ATP is hydrolysed to ADP (adenosine diphosphate)

Atrophy: The wasting of tissues, organs or the entire body.

Autotrophic: Plants or certain microorganisms capable of manufacturing their own food from inorganic materials, as in photosynthesis.

Axil: Angle between the upper surface of a leafstalk, flower stalk, branch, or similar part, and the stem or axis from which it arises.

Axillary: Located in an axil (axillary buds).

Axon: Long unbranched process extending from cell body of a nerve cell. Generally conducts impulses away from the nerve cell.

Azotobacter: A nitrogen fixing bacteria.

Bacillus: Any rod-shaped bacterium.

Barb: Parallel filaments projecting from the main shaft of a feather.

Bark: The protective outer covering of the woody stems, branches, and main trunks of trees and other woody plants, consisting of dead cells.

Basal metabolic rate: The rate at which energy is used by an organism at complete rest, expressed in terms of heat production per unit of body surface area per day.

Basal metabolism: The least amount of energy required to maintain vital functions, such as respiration and digestion, in an organism at complete rest.

Bast: Fibrous, outer layer of stems of certain plants (flax, hemp), used to make cordage and textiles. Also a plant tissue, phloem.

Biennial: Having a normal life cycle of two years.

Bifid: Divided or cleft into two parts or lobes.

Biflagellate: Having two flagella: a biflagellate protozoan.

Bifoliate: Having two leaves.

Bilabiate: Having two lips. Said of a flower or corolla.

Bilateral symmetry: The arrangement of the parts of an organism or organ such that it can be divided into two halves that are mirror images of each other along only one plane.

Bile duct: Any duct that drain bile from the liver. They join to form the common bile duct, which opens into the duodenum.

Bile: A bitter, alkaline, greenish-yellow liquid secreted by the liver, stored in the gall bladder, and discharged into the duodenum, where it aids in digestion, chiefly by emulsifying fats so that they can be more easily absorbed. It contains pigments bilirubin and biliverdin.

Binary fission: Fission, especially of a cell nucleus, that results in just two approximately equal products.

Biocatalyst: A substance, especially an enzyme, that initiates or modifies the rate of a biological process.

Biodegradable: Capable of being decomposed by natural biological processes.

Biological control: The control of pests using other organisms, usually their natural predators, parasites or diseases.

Biology: The science of life and life processes, including the study of structure, functioning, growth, origin, evolution, ecology and distribution of living organisms.

Biophysics: The physics of biological processes and the use of techniques of physics in studying biology.

Biped: An animal with two feet.

Bipetalous: Having two petals.

Bipinnate: Having opposite leaflets that are subdivided into opposite leaflets. Said of compound leaves.

Bisexual: Having both male and female organs; hermaphroditic.

Bivalve: Mollusc having a shell consisting of two dorsally hinged valves, e.g., oysters, cockles, clams, scallops and mussels.

Black-head: A plug of dried fatty matter capped with blackened dust and epithelial debris that clogs a pore of the skin.

Bladder: Distensible membranous sacs found in most animals, especially the urinary bladder.

Blood count: The number of red and white blood cells in a specific volume of blood.

Blood donor: A person who gives blood for transfusion.

Blood group: Distinct, genetically determined classes of human blood, clinically identified by characteristic agglutination reactions based on the presence or absence of certain antigens.

Blood poisoning (septicaemia): Blood contains poisons or the bacteria that produce them.

Blood vessel: Any elastic, tubular canal, such as an artery, vein, or capillary, through which blood circulates.

Blood: Fluid circulated by the heart through the vascular system, carrying oxygen and nutrients throughout the body and waste materials to excretory channels. It consists of blood plasma in which are suspended red blood cells (erythrocytes), white cells (leucocytes), and platelets.

Blubber: The thick layer of fat between the skin and the muscle layers of whales and other marine mammals.

Blue-green algae: Algae of the division Cyanophyta, considered to be among the simplest forms of plants.

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Body cavity: The internal cavity of all multicellular animals except sponges, which contains the digestive tract, and many other organs.

Body wall: The part of an animal's body that encloses the body cavity, made up of ectoderm and mesoderm.

Boil: Painful swelling of the skin and subcutaneous tissue with a hard pus-filled centre, caused by bacterial infection, usually occurring at a hair follicle.

Bole: The trunk of a tree.

Bolus: A soft, small, round mass, particularly of chewed food.

Bone: Dense, semirigid, porous, calcified, connective tissue of the skeleton of most vertebrates.

Botany: The study of plants, covering their classification, form, function, ecology and economic importance.

Bowman's capsule: Cup-shaped end of a kidney tubule that surrounds a knot of blood capillaries and with them forms the Malpighian body.

Bract: A leaflike plant part, usually small ,sometimes showy and brightly coloured, located below a flower or an inflorescence.

Bread mould: A fungus, e.g., *Rhizopus nigricans*, that forms a dense, cottony growth on bread and other foods.

Brittle star: Marine organisms related to and resembling the starfish but having long, slender, whiplike arms.

Bronchiole: Fine, thin-walled, tubular extensions of a bronchus.

Bronchitis: Chronic or acute inflammation of the mucous membrane of the bronchial tubes. Symptoms include coughing and breathing difficulties.

Bronchus: Either of two main branches of the trachea, having walls thickened with cartilage and branching into smaller air passages, leading directly to the lungs.

Brown fat: Adipose tissue whose oxidation is a major source of heat in mammals.

Bryophyte: Plant of the botanical division Bryophyte, e.g., mosses and liverworts. Bryophytes have stems and leaves but lack true roots and vascular tissue.

Bubonic plague: A contagious often fatal epidemic disease caused by the bacterium *Pasteurella pestis,* transmitted by fleas from infected rats and characterised by chills, fever, vomiting, diarrhoea and buboes.

Buccal: Of or pertaining to the cheeks or mouth.

Bud: An outgrowth on a stem or branch, often enclosed in protective scales, comprising a shortened stem and immature leaves or floral parts ; An asexually produced outgrowth, as on a polyp, yeast that develops into a mature, complete organism.

Bulb: A modified underground stem, e.g., onion, tulip. Usually surrounded by scalelike modified leaves. Contains stored food for the undeveloped shoots of the new plant enclosed within it.

Bulbil: A small bulblike part growing above ground on a flower stalk or in a leaf axil.

Buttress root: A root growing from and supporting the trunk of a tree, as in the mangrove.

Cactus: Plants mostly native to arid regions characterised by thick, fleshy, often prickly stems that function as leaves.

Caecum: A blind-ended pouch marking the junction of the small and large intestines.

Calciferol: One of the forms in which vitamin D occurs.

Calcium: A silvery, moderately hard metallic element, which is a basic component of bone, shells, and teeth.

Cambium: A layer of cells in the stems and roots of vascular plants that gives rise to phloem and xylem and thus increases the girth of the plant.

Cancer: Malignant tumours, caused by abnormal division of cells, which invade surrounding tissues and often spread to other parts of the body through the blood or lymph.

Cardiac arrest: The cessation of effective pumping of blood by the heart, resulting in loss of consciousness, absence of the pulse, and cessation of breathing.

Cardiac muscle: The striated muscle of the heart.

Carnivore: Animal belonging to the order Carnivora, which includes predominantly flesh-eating mammals. Any flesh-eating or predatory organism, such as a bird of prey or an insectivorous plant.

Carotene: A water insoluble plant pigment which may be converted to vitamin A in the liver.

Carotenoid: Yellow to deep red pigments, such as the carotenes, occurring in many vegetable oils and some animal fats.

Carpals: Bones of the wrist.

Carpel: The central, ovule-bearing female organ of a flower, consisting of an ovary, style, and stigma. Carpels may be separate or fused to form a single pistil.

Cartilage: A tough fibrous connective tissue attached at the joints between bones.

Cartilaginous fish: Any fish having a skeleton entirely made up of cartilage, e.g., shark, skates, and rays.

Casparian strip: A band of thickening in the walls of certain plant stem surrounding the conducting tissues, forming a ring impervious to liquids and gases. Also called "Casparian band".

Catabolism: The metabolic change of complex molecules into simple molecules with the release of energy; destructive metabolism.

Cell division: The process by which a cell gives rise to two daughter cells.

Cell wall: The rigid outermost layer of a plant cell, consisting of cellulose and other polysaccharides.

Cell: The smallest structural unit of an organism that is capable of independent functioning, consisting of one or more nuclei, cytoplasm, various organelles, and inanimate matter, all surrounded by a semipermeable plasma membrane. Plant cells have cellulose outer cell walls.

Cellulose: A polysaccharide of high tensile strength, the main constituent of plant cell walls and used in the manufacture of many fibrous products, including paper, textiles, and explosives.

Centriole: Either of two tiny cylindrical organelles in most animal cells that form the poles of the spindle during mitosis.

Cervix: The neck region ; The narrow outer end of the uterus.

Chalaza: *Zoology:* Either of the two spiral bands of tissue in an egg, connecting the yolk to the lining membrane. *Botany:* Part of an ovule that is opposite the micropyle and serves as a point of attachment for the integuments and the nucellus.

Chemosynthesis: The synthesis of organic substances from carbon dioxide, by certain bacteria using the energy of chemical reactions.

Chemotropism: Growth of an organism, especially a plant, in response to chemical stimuli.

Chlorophyll: Green pigments found in plants that trap energy from sunlight for use in photosynthesis.

Chloroplast: Plastid containing chlorophyll in photosynthetic plants.

Cholera: Infectious epidemic disease caused by the bacterium *Vibrio comma,* characterised by watery diarrhoea, vomiting, cramps, suppression of urine, and collapse.

Cholesterol: A universal tissue constituent, occurring notably in bile, gallstones, the brain, blood cells, and plasma.

Chordate: Animals belonging to the phylum Chordate, e.g., vertebrates and certain marine animals having a notochord.

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Chromatin: A complex of nucleic acids and proteins in the nucleus of a cell.

Chromatophore: A pigment containing, or pigment producing cell, especially in animals.

Chromosome: Threadlike structures in the cell nuclei of organisms. They bear genes which are responsible for the determination and transmission of hereditary characteristics.

Chyme: Thick semifluid mass of partly digested food in the stomach that passes into the duodenum.

Cilia: Microscopic hairlike growths extending from the surface of a cell or organism. Their rhythmical beating causes movement of the cell or the surrounding medium.

Circulatory system: The system of vessels by which blood is circulated throughout the body by the heart.

Cirrhosis: Chronic disorder of the liver, in which normal tissue is replaced by fibrous tissue, caused by alcoholism or hepatitis.

Clavicle (collarbone): Bones connecting the upper part of the breastbone with the shoulder blades.

Clitellum: Swollen, glandular, saddle-like region in the epidermis of certain annelids, e.g., earthworm. Binds worms together during copulation.

Cloaca: The cavity into which the intestinal, genital and urinary tracts open in vertebrates such as fish, reptiles, birds and some primitive mammals.

Clone: One or more organism descended asexually from a single ancestor.

Coccus: Bacterium with a spherical or spheroidal shape.

Coccyx: In humans and certain apes, a small bone at the base of the spinal column, consisting of several fused rudimentary vertebrae, which represents a vestigial tail.

Cocoon: A covering of silk or fibrous material spun by the larvae of moths and other insects to protect their pupal stage.

Coelom: Body cavity in all animals higher than the coelenterates.

Coenocyte: Organism consisting of a multinucleate protoplasmic mass resulting from nuclear division without the formation of a new cell wall or membrane.

Coenzyme: A heat-stable organic molecule that must be loosely associated with certain enzymes for them to function.

Cold-blooded: Having a body temperature that varies with the external environment; poikilotherm.

Coleoptile: A leaflike structure in grasses and similar monocotyledons, forming a protective sheath around the plumule.

Coleorhiza: A protective sheath around the embryonic root of grasses and similar monocotyledons.

Collagen: A fibrous protein occurring in bone, cartilage, and connective tissue.

Collenchyma: Supportive tissue of plants. Consists of elongated, rectangular cells with walls thickened with cellulose and pectin.

Colon: The section of the large intestine extending from the caecum to the rectum.

Compound leaf: A leaf consisting of two or more separate leaflets borne on a single leafstalk.

Compound microscope: A microscope consisting of an objective and an eyepiece, at opposite ends of an adjustable tube.

Cone: A conical, or cylindrical structure borne by gymnosperms consisting of clusters of stiff, overlapping, woody scales, between which are the naked ovules ; A photoreceptor in the retina of the eye that is sensitive to colour and bright light.

Conifer: Gymnosperm tree, typically evergreen and bearing cones.

Conjugation: Process of sexual reproduction in ciliate protozoans, some algae and bacteria, in which two individuals of the same species temporarily couple and exchange genetic material.

Connective tissue: Tissue consisting of a jelly-like matrix in which are embedded collagen and elastic fibres, fat cells, fibroblasts, mast cells. It supports and separates organs and occurs in tendons, ligaments, cartilage and bone.

Constipation: Difficult, incomplete, or infrequent evacuation of the bowels.

Contagious: Transmissible by direct or indirect contact; communicable, e.g., disease like cholera.

Contour feather: Outermost feathers of a bird, forming the visible body contour and plumage.

Contractile vacuole: Vesicle found in many protozoa that expels water to the exterior and so regulates water content.

Control experiment: An experiment designed to check or verify a parallel experiment or as part of a set of experiments testing the effects of a variable or variables, in which the variable factors are controlled so that the effects of changing one at a time can be observed.

Cork cambium: A layer of continually dividing cells situated near the surface of woody plant stems and roots, which forms cork to the outside and secondary cortical cells to the inside.

Cork: Light, porous, elastic outer bark of the cork oak, used as an insulator and a stopper for bottles.

Corm: An underground stem, e.g. gladiolus, similar to a bulb but having papery, rather than fleshy, scale leaves.

Corona: A crownlike part of a flower, usually between the petals and stamens. Sometimes an appendage of the corolla, as in daffodils.

Corpuscle: A cell, such as an erythrocyte or leucocyte, that is capable of free movement in a fluid or matrix, as distinguished from a cell fixed in tissue.

Cortex: The outer layer of an organ or part, as of the kidney, adrenal gland, cerebrum or cerebellum; A layer of tissue in roots and stems lying between the epidermis and the vascular tissue. An external layer such as bark or rind.

Corymb: A flat-topped flower cluster in which the individual stalks grow upwards from various points of the main stem to approximately the same height.

Cotyledon: A simple leaf of a plant embryo, which is one of the first to appear from the sprouting seed . Acts as a food store in many seeds. Also called "seed leaf".

Cowpox: A contagious viral disease of cattle characterised by vesicles on the skin, especially the udder. Inoculation of humans with cowpox virus confers temporary immunity to small-pox.

Cranium: Portion of skull of a vertebrate enclosing the brain and made up of eight bones connected by immovable joints.

Crustacean: Predominantly aquatic arthropods, e.g., lobsters, crabs, shrimps, and wood lice, having a segmented body, a chitinous exoskeleton, and paired, jointed limbs.

Cuspid: A tooth having one point; a canine tooth.

Cuticle: Strip of noncellular, hardened skin at the base of a fingernail or toenail forming a protective outer covering in many invertebrates; The protective layer of cutin covering the epidermis of plants.

Cyanocobalamin: Vitamin B12.

Cycad: Seed-bearing gymnosperm plant resembling a palm tree but surmounted by fernlike leaves.

Cyclosis: The circulatory motion of protoplasm or organelles within certain cells and single-celled animals.

Cyme: Flat-topped flower cluster that blooms from the centre towards the edges. Main axis always terminates in a flower.

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Cyst: Any sac or vesicle in the body; A capsule-like membrane enclosing certain organisms in a resting stage.

Cytology: The branch of biology dealing with the study of the formation, structure, and function of cells.

Cytoplasm: The protoplasm outside a cell nucleus.

DDT (di-chloro di-phenyl tri-chloroethane): Insecticide, toxic to man and animals.

Deciduous: Shedding or losing foliage at the end of the growing season: deciduous trees.

Defecate: To discharge faeces from the bowels.

Dehydration: Excessive loss of water from the body, organ or bodily part.

Dendrite: In a nerve cell, a fine branch of a dendron.

Dendron: Protoplasmic process of nerve cell, conducts impulses towards cell body.

Dengue: Infectious, viral disease spread by mosquitoes and characterised by fever, rash, and severe pain in the joints.

Denitrifying bacteria: Soil bacteria, reduces nitrate to ammonia.

Dental hygiene: Maintenance of healthy teeth and gums.

Dental plaque: A film containing bacteria and other substances that forms on the surface of a tooth. Also called "plaque'.

Dentine: The calcareous part of a tooth, beneath the enamel, containing the pulp chamber and root canals.

Dentition: Type, number and arrangement of teeth, especially in humans and other animals. Process of cutting new teeth; teething.

Deoxygenate: To remove oxygen.

Dermatology: The branch of medicine concerned with the physiology and pathology of the skin and treatment of skin diseases.

Dermis: Living part of skin. Forms a thick layer below epidermis. Consists of connective tissue with blood and lymph vessels, nerve endings, sweat and sebaceous glands, and smooth muscle.

Dhobi's itch: A fungal skin disease, supposedly contracted from other people's dirty clothes.

Diadelphous: Stamens in two bundles due to fusion of filaments.

Dialyser: An apparatus for performing dialysis, especially a kidney machine.

Dialysis: The separation of smaller molecules from larger molecules, or of crystalloid particles from colloidal particles, in a solution by selective diffusion through a semipermeable membrane.

Diapedesis: The passing of blood or any constituents, especially leucocytes, through intact blood vessel walls.

Diaphragm: A muscular membranous partition separating the abdominal and thoracic cavities in mammals.

Diaphragm: A muscular membranous partition separating the abdominal and thoracic cavities and functioning in respiration;

Diarrhoea: Excessive and frequent evacuation of watery faeces.

Diastole: The normal rhythmically occurring relaxation and dilatation of the heart cavities, during which the cavities are filled with blood.

Dicotyledon: Division of angiosperms, characterised by a pair of embryonic seed leaves that appear at germination

Didynamous: Four stamens arranged in pairs, differ in length.

Digest: To transform (food) into an assimilable condition.

Digestion: Enzymatic bodily process by which foods are converted into simple, assimilable substances.

Digestive system: The alimentary canal together with accessory gland regarded as an integrated system responsible for digestion.

Dioecious: Male and female flowers borne on separate plants.

Diphyodont: Having two successive sets of teeth, e.g., humans.

Diploblastic: Have two distinct cellular layers, e.g., coelenterates.

Diplococcus: Paired spherical bacteria.

Disaccharide: Class of carbohydrates that yield two monosaccharides on hydrolysis, e.g., lactose and sucrose.

Disc flower (disc floret): Tiny, tubular flowers forming the centre of the flower head of certain composite plants, e.g., daisy.

Duct: Any tubular passage through which a substance, especially a fluid, is conveyed.

Duodenum: The portion of the small intestine starting at the lower end of the stomach and extending to the jejunum.

Dysentery: An infection of the lower intestinal tract producing pain, fever, and severe diarrhoea, often with blood and mucus.

ECG: Electrocardiogram, electrocardiograph.

Echinoderm: Marine invertebrates with calcareous skeleton just beneath the skin, often covered with spines, e.g. star fish.

Ectoderm: Outermost of the three primary germ layers of an embryo. Develops into epidermis, nervous tissue.

Efferent: Nerves that carry impulses from the central nervous system to an effector.

Egest: To discharge or excrete from the body.

Elephantiasis (filaria): Extreme enlargement and hardening of cutaneous and subcutaneous tissue of the legs and scrotum due to lymphatic obstruction, caused by worm, *Wuchereria bancrofti.*

Embryo sac: Oval cell in which embryo develops in seed plants.

Embryo: An organism in its early stages of development, especially before it has reached a distinctively recognisable form.

Embryology: The science dealing with the formation, early growth, and development of living organisms.

Emu: A large, flightless Australian bird.

Enamel: Hard calcium-containing material, covers exposed part of tooth.

Endemic: Recurring in a particular locality. Said of a disease.

Endocarp: Hard or leathery inner layer of pericarp of many fruits.

Endoderm: Innermost of the three primary germ layers of embryo. Develops into lining of intestinal tract and its derivatives.

Endodermis: Innermost of the cortex, found in all roots and in the stems of certain plants, which controls the passage of water.

Endoparasite: Organism lives parasitically within another (host).

Endoplasm: Inner, less viscous portion of the cytoplasm.

Endoplasmic reticulum: A system of membrane bounded sacs in the cytoplasm of cells that functions in intracellular transport.

Endosperm: The nutritive tissue surrounding and absorbed by the embryo in flowering plants.

Enucleate: To remove the nucleus of (a cell). Lacking a nucleus.

Enzyme (biocatalyst): Proteins or conjugated proteins produced by living organisms and functioning as biochemical catalysts.

Eosinophil: Leucocyte with lobed nucleus that stains with an eosin dye.

Epicalyx: A set of bracts close to and resembling a calyx.

Epicardium: The inner layer of the pericardium that is in actual contact with the heart.

Epicotyl: The part of the stem of a seedling or embryonic plant that is above the cotyledons and below the first true leaves.

Epidemic: Rapid and extensive spread of contagious disease.

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Epidermis: Outer, protective layer of cells in vertebrates (skin). Invertebrates, covering of a plant or plant part.

Epigeal: Germination in which cotyledons come above the soil.

Epiglottis: Elastic cartilage at the root of tongue. It folds over the glottis, prevents food from entering the windpipe while swallowing.

Epigyny (inferior ovary): Petals, sepals and male organs are above the ovary.

Epithelium: Membranous tissue, usually single layered, composed of closely arranged cells. Forms the covering of most internal surfaces and organs and the outer surface of an animal body.

Erepsin: Enzyme in ileum, converts proteins into amino acids.

Erythrocyte (red blood cell): A non-nucleated, disc shaped blood cell containing the red pigment haemoglobin, which transports oxygen and carbon dioxide around the body.

Erythropoiesis: The process by which erythrocytes are formed.

Etiolate: To cause (a plant) to develop without normal green colouring by preventing exposure to sunlight.

Eukaryote: Genetic material is enclosed by a membrane to form nucleus. All organisms except bacteria, blue-green algae, virus.

Ever-green: Plants that do not shed all the leaves at the same time.

Excreta: Waste excreted from the body, e.g., sweat, urine, faeces.

Excrete: Remove waste matter from the blood, tissues or organs.

Excretion: The process or act of excreting undigested food residues or metabolic wastes.

Eye: An organ of vision ; A bud on a twig or tuber, e.g., potato.

Family: Taxonomic category, below an order and above a genus.

Fatty acid: Monobasic acids obtained from animals and plants.

Femoral: Pertaining to the thigh or the femur.

Fermentation: Chemical reactions that split complex organic compounds into relatively simple substances, e.g., anaerobic conversion of sugar to carbon dioxide and ethanol by yeast.

Fertilisation: The process in which two gametes unite to form a zygote.

Fibre: Elongated, thick-walled cells that give strength and support to plant tissue; Filaments constituting the intracellular matrix of connective tissue.

Fibrin: An elastic, insoluble protein derived from the interaction of fibrinogen with thrombin and forming a fibrous network in the coagulation of blood.

Fibrinogen: A protein in the blood plasma that is converted to fibrin by the action of thrombin in the presence of ionised calcium, in blood coagulation.

Fibula: The outer and smaller of two bones of the human leg or the hind leg of an animal, in humans between the knee and ankle.

Filament: The slender stalk of a stamen on which the anther is borne; A chainlike series of cells, as in some algae and bacteria. The free barb of a down feather.

Flower: Reproductive structure of an angiosperm having male and female organs enveloped within petals and sepals.

Fluorosis: Mottling of teeth due to excessive intake of fluorides.

Follicle: Cavities in the ovary containing ova; A single chambered fruit that splits along only one seam to release its seeds.

Fossil: A remnant or trace of an organism of a past geological age, (skeleton, footprint, leaf imprint), embedded in the earth's crust.

Frog: Tailless, chiefly aquatic amphibians having a smooth, moist skin, webbed feet, and long hind legs adapted for leaping.

Frontal bone: Cranial bone consisting of vertical portion corresponding to the forehead and a horizontal portion that forms the roofs of the orbital and nasal cavities.

Fructose: Very sweet sugar C6H12O6, occurring in many fruits.

Fruit: The ripened ovary or ovaries of a seed-bearing plant.

Fruiting body: Specialised spore-producing structure of fungus.

Fungus: Organism lacks chlorophyll and is therefore parasitic or saprophytic.

Funny bone: Point near the elbow which if accidentally knocked, produces a tingling sensation.

Gall bladder: Small, pear-shaped, muscular sac located under the right lobe of the liver, in which bile secreted by the liver is stored.

Gametangium: Organ or cell in which gametes are produced.

Gamete: A mature sperm or egg containing haploid number of chromosomes, capable of participating in fertilisation.

Gamma globulin: Part of blood plasma containing antibodies.

Gamopetalous: Corolla with the petals fused or partially fused.

Gamosepalous: Sepals united or partly united.

Gastric juice: Acidic digestive fluid secreted by the gastric glands of stomach. Contains hydrochloric acid, pepsin, renin, and mucin.

Gene: A hereditary unit located on a chromosome that determines a specific characteristic or function in the organism.

Geotropism: The response of a plant organ to gravity.

Germinate: To bring into existence.

Gill bar: Any of a series of skeleton structures in the pharyngeal wall of fishes that supports the tissue separating the gill slits.

Gill: Respiratory organ of fishes, larval amphibians, and numerous aquatic invertebrates. Consists of a membranous appendages well supplied with blood vessel for gaseous exchange.

Gland: An organ that synthesizes and secretes specific substances, such as hormones and enzymes.

Glomerulus: A tuft of capillaries situated within the capsule at the end of a urine-secreting tubule in the vertebrate kidney.

Glucose: A white monosaccharide sugar, $C_6H_{12}O_6$.

Glume: A chaffy basal bract on the spikelet of a grass.

Glycogen: Main form in which carbohydrate is stored in animals

Glycolysis: The biochemical breakdown of glucose to lactic acid, with the production of energy in the form of ATP.

Goblet cell: Pear-shaped cells in vertebrate epithelium that secretes the chief constituents of mucus.

Goitre: Enlargement of the thyroid gland, visible as a swelling at the front of the neck, associated with iodine deficiency.

Golgi Apparatus: Membranous vesicles in living cells believed to function in the formation of secretions within the cell. Also called "Golgi Body", "Golgi Complex".

Gout: A disturbance of uric-acid metabolism, occurring predominantly in males, in which deposits of urates accumulate in the joints, especially those of the big toe, and cause arthritic attacks.

Graft: (In horticulture) To unite a shoot or bud with a growing plant by insertion or placing in close contact.

Ground tissue: Plant tissues, such as pith and cortex, that are not specialised for a particular function.

Growth: Development from a lower or simpler to a higher or more complex form; An increase in size, number, or strength.

Guard cell: Either of the paired epidermal cells that control the opening and closing of a stoma in plant tissue.

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Guard cell: Epidermal cells that control the opening and closing of a stoma in plant tissue.

Gum: Viscous substance exuded by certain plants; Firm connective tissue that envelops the bones of the jaw and surrounds the bases of the teeth.

Gut: Portion of alimentary canal , especially intestine or stomach.

Gymnosperm: Plants having seeds not enclosed within an ovary.

Gynoecium: Female reproductive organs of a flower; the pistil.

Habitat: Type of environment in which an organism or biological population normally lives or occurs.

Haemoglobin: The oxygen-bearing, iron-containing conjugated protein in vertebrate red blood cells.

Haemophilia: A hereditary blood coagulation disorder, principally affecting males but transmitted by females.

Haemorrhage: Bleeding; heavy discharge of blood from vessels.

Haemostasis: The stopping of the flow or circulation of blood.

Hair: Cylindrical filaments growing from epidermis of mammal.

Haversian canal: Fine interconnecting channels that carry the blood and nerve supply in bones.

Heart: Hollow, muscular organ in vertebrates that pumps blood through the circulatory system; It is divided vertically into two halves, each having an upper atrium and a lower ventricle.

Heat stroke (sunstroke): Caused by exposure to excessively high temperatures. Characterised by severe headache and high fever

Heparin: A complex organic acid having the ability to prevent the clotting of blood.

Hepatitis: Inflammation of liver characterised by fever, weakness.

Herb: Angiosperm plant with soft fleshy stem.

Herbivorous: Feeding on plants; plant-eating.

Hermaphrodite: Having sex organs and several secondary sex characteristic of both male and female.

Herpes: Viral diseases causing eruption of skin.

Heterodactyl: Designating a bird's foot on which the first and second toe point backwards and the third and fourth forwards.

Heterodont: Teeth of various different kinds. Said of mammals.

Heterotrophic: Obtaining nourishment from organic substances, as do all animals and some plants.

Hibernate: To pass the winter in a dormant state. Inactive.

Hilum: Scar on a seed at the point where it was joined to the stalk connecting it to placenta; The nucleus of a starch grain.

Histology: Anatomical study of the microscopic structure of animal and plant tissue.

Holophytic: Manufacture of food by photosynthesis.

Holozoic: Obtain nourishment from complex organic material.

Homeostasis: A state of physiological equilibrium produced by a balance of functions and of chemical composition within an organism.

Homodont: Having teeth that are all of the same kind. Said of most vertebrates except mammals.

Homoiothermic (warm-blooded): Maintain relatively constant body temperature, independent of environmental temperature.

Homosapiens: The taxonomic designation for modern man.

Hormone: Chemical substance, affects growth in plants, animals.

Hyaloplasm: Fluid portion of cytoplasm.

Hybrid: Offspring of genetically dissimilar parents or stock.

Hydra: Fresh water polyps having naked, cylindrical body and an oral opening surrounded by tentacles.

Hygiene: The science of health and the prevention of disease.

Hyoid bone:

Hypha: Thread-like filaments forming the mycelium of a fungus.

Hypocotyl: Axis of plant embryo or seedling below cotyledons.

Hypogeal: Germination in which cotyledons remain below the surface of the ground.

Hypogynous (superior ovary): Floral parts or organs that are below and not in contact with the ovary.

Hypothalamus: Part of brain that lies below the thalamus, and regulates bodily temperature, hunger, thirst.

Ichthyology: Study of fishes.

Ileum: Part of small intestine extending from jejunum to caecum.

Ilium: Uppermost and widest of the three bones of the pelvis.

Imago: Sexually mature stage of insect after metamorphosis.

Immunology: The study of immunity to disease.

Impermeable: Not allowing the passage of fluids.

Incisor: Tooth adapted for cutting, located at the front of mouth.

Inclusion: Any non-living mass in cytoplasm.

Incubation: Development of infection from the time an organism is first exposed to it, until the first appearance of symptoms.

Incus: An anvil-shaped bone in the mammalian middle ear.

Infection: Invasion of the body by pathogenic microorganisms.

Infectious: Transmitted by infection without actual contact.

Inflammation: Localised heat, redness, swelling, and pain.

Inflorescence: Arrangement of flowers on a single main stalk.

Influenza (flu): Infectious viral disease characterised by inflammation of the respiratory tract, fever and muscular pain.

Ingest: To take into the body (food).

Innominate artery: A short artery that arises from the aortic arch and divides in the neck to form the right common carotid and right subclavian arteries.

Innominate vein: Veins in the neck formed by the union of the internal jugular and subclavian veins. The innominate veins join to form the superior vena cava.

Inoculate: Virus of a disease, or other antigenic material introduced into the body of a person or animal in order to immunise.

Insect: Invertebrate animal. Adult stage has three pairs of legs, body with three major divisions, and usually two pairs of wings.

Insectivorous: Capable of trapping and absorbing insect.

Integument: An outer covering, e.g., skin, coat of a seed.

Intercalary: Non-localised plant growth occurring at internodes

Intercellular: Among or between cells.

Intercostal: Located or occurring between the ribs.

Internode: A section or part between two successive nodes.

Intestinal flora: Harmless and beneficial bacteria in the intestine.

Intestine: Portion of alimentary canal from stomach to anus.

Invertase (sucrase): Enzyme. Converts sucrose to glucose, fructose.

Invertebrate: Having no back bone or spinal column.

Involucre: Whorl of bract around a flower or flower cluster.

Irradiate: To expose to radiation.

Ischaemia: Lack of sufficient blood (oxygen) to a part due to obstruction of circulation.

Ischium: The lowest of three major bones comprising the pelvis.

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Isogamete: A gamete that is morphologically indistinguishable from one with which is unites.

Jejunum: Part of small intestine between duodenum and ileum.

Jenner, Edward: British physician and pioneer of vaccination.

Jenner: British physician and pioneer of vaccination. In 1796 he found that smallpox could be prevented by inoculation with the substance from cowpox lesions.

Jugular vein: Veins in the neck conveying blood from the brain, face, and neck to the subclavian vein. The external jugular is a smaller paired vein taking blood from the face, scalp, and neck to the subclavian vein.

Keratin: A tough, fibrous protein forming the outer layer of epidermal structures such as hair, nails, horns and hoofs.

Kidney: Organ, acts to remove metabolic wastes from the blood.

Kingdom: The broadest taxonomic category of organisms.

Kwashiorkor: Severe malnutrition due to protein deficiency generally affecting children below 5 years of age. Child becomes weak, listless, and the liver is damaged.

Labium: A liplike structure, forming the lower lip in insects.

Lactase: Enzyme. Converts lactose into glucose and galactose.

Lamina: The expanded area or blade, of a leaf or thallus.

Large intestine: Part of intestine that extend from the ileum to the anus. Includes the caecum, colon, and rectum.

Larva: Early form of an organism which is very unlike the parent and undergoes great changes to become an adult.

Laryngitis: Inflammation of the larynx, causing hoarseness and sometimes temporary loss of speech.

Larynx: The upper part of the respiratory tract between the pharynx and the trachea, having cartilaginous walls and containing the vocal cords.

Lateral line: A series of sensory pores and tubes for sensing sound and vibration, along the side of a fish.

Latex: Milky, viscous plant sap that coagulates on exposure to air.

Layering: The process of rooting branches, twigs, or stems that are still attached to a parent plant,

Leaf stalk: The stalk by which leaf is attached to a stem; a petiole.

Leaf: Usually green, flattened structure of vascular plants functioning as a principal organ of photosynthesis and transpiration.

Leeuwenhoek: Dutch naturalist, pioneer in microscopy.

Legume: A pod, that splits into two halves with the seeds attached to the lower edge of one of the halves, e.g., pea, bean.

Lemma: Outer, lower bract enclosing flower in a grass spikelet.

Lenticel: Small pores on stem surface of the woody plants, allowing the passage of gases to and from the interior tissue.

Leucocyte: Colourless nucleated cells occurring in blood. Also called "white blood cell", "white corpuscle".

Leucoderma: Partial or total lack of skin pigmentation.

Leucoplast: A colourless plastid in the cytoplasm of plant cells, around which starch collects.

Leucopoiesis: The process by which white blood cells are formed.

Leukaemia: Usually fatal disease involving uncontrolled proliferation of leucocytes, which suppress the production of normal blood cell.

Ligament: Sheet of tough, fibrous tissue binding bones or cartilages.

Ligule: Sheath-like organ at the base of a grass leaf; Strap-like structure such as a ray-floret.

Lipase: Enzyme. Hydrolyses fats to form glycerol and fatty acids.

Lymph node: Oval or round bodies, located along the lymphatic vessels, that supply lymphocytes to the circulatory system and remove bacteria and foreign particles from the lymph.

Lymph: Clear, transparent, watery, sometimes faintly yellowish liquid, derived from body tissues, that contains mainly white blood cells. It acts to remove bacteria and certain proteins from the tissues, to transport fat from the intestines, and to supply lymphocytes to the blood.

Lymphatic system: The interconnected system of spaces and vessels between tissues and organ by which lymph is circulated throughout the body and returned to the venous system.

Lymphocyte: A white blood cell constituting between 22 to 28 per cent of all leucocytes in the normal adult human's blood.

Lysosome: Cell organelle that contains enzymes capable of breaking down substances in the cell.

Macronutrient: Element required in relatively large proportion for growth, e.g., carbon, hydrogen, oxygen, nitrogen.

Malaria: Infectious disease, transmitted by female anopheles mosquito infected with a protozoan parasite of genus *Plasmodium*.

Malnutrition: Condition resulting from lack of adequate nutrition. It is caused by an insufficient or ill-balanced diet or by defective digestion or utilisation of food.

Malpighian body: A mass of arterial capillaries enveloped in a capsule and attached to a tubule in the kidney. Also called "Malpighian corpuscle".

Malpighian layer: Deepest layer of the epidermis

Maltase: An enzyme that hydrolyses maltose to glucose.

Maltose: A sugar formed during the digestion of starch

Melanin: A dark pigment found in the skin, retina, and hair.

Mesocarp: The middle, usually fleshy layer of a pericarp.

Mesoderm: The embryonic germ layer, lying between the ectoderm and the endoderm, from which develop connective tissue, muscles, and urogenital and vascular systems.

Mesoglea: Separates inner and outer cell layers in coelenterates.

Mesophyll: The soft tissue of a leaf, between upper and lower epidermis, that contains chloroplasts.

Mesothorax: The middle section of insect's thoracic region, bearing the middle legs and the front wings.

Metabolism: The complex of physical and chemical processes involved in the maintenance of life.

Metacarpus: Five bones between fingers and wrist in mammals.

Microsporophyll: Structure in ferns that bears microsporangia.

Mitochondria: A microscopic body or organelle found in the cytoplasm of eukaryotic cells, consisting of two sets of membranes. The inner membrane is invaginated, and is the site of energy production by the process of cellular respiration.

Myocardial infarction: Death of a section of heart muscle that occurs when its blood supply is obstructed by coronary thrombosis, characterised by severe pain in the chest.

Nematocyst: Stinging organ in various coelenterates.

Nematode: Worms of the phylum Nematoda, having unsegmented, threadlike bodies. Body cavity absent.

Nephridium: Excretory organ in many invertebrates, consisting of a tube through which waste products pass to the exterior.

Nephron: Excretory units of the kidney, consisting of a tiny, coiled

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tubule into which urine is filtered from the blood.

Nerve cell: Cells of nerve tissue. It consist of a nucleated cell body and cytoplasmic extension. Also called "neurone".

Nerve fibre: A threadlike process that is part of a nerve cell; an axon.

Nervure: Vascular ridges that form the framework of a leaf; Ribs of tissue that form the framework of an insect's wing.

Neurilemma: The outer covering of a nerve fibre.

Neutrophil: A phagocytic leucocyte of a type having a lobed nucleus and granular cytoplasm that stains with neutral dye.

Night blindness: Poor vision in the dark.

Nipple: Small conical protuberance near the center of the mammary gland in females containing the outlets of the milk ducts.

Nissl's granules: Rough endoplasmic reticulum in the cell bodies of neurons that functions in protein synthesis.

Nocturnal: Active chiefly at night, resting during the day.

Nomenclature: A system of names or terms.

Notochord: A flexible rod-like structure in some lower vertebrates that provides dorsal support. In higher vertebrates, it gives rise to the spine.

Nucellus: Center of ovule of a plant, containing the embryo sac.

Nucleic acid: Complex compounds found in all living cells, and composed of purines, pyrimidines, sugars, and phosphoric acid.

Nucleolus: A small, usually round body composed of protein and RNA in the nucleus of a cell. Also called "plasmosome".

Nucleoplasm: The protoplasm of a cell nucleus.

Nucleus: A complex, usually spherical, protoplasmic body within a living cell that contains the cell's hereditary material and that controls its metabolism, growth, and reproduction.

Nymph: Young of insects, such as the mayfly or dragonfly, that undergo incomplete metamorphosis.

Occipital bone: Forms the lower posterior part of the skull.

Oedema: An excessive accumulation of fluid in the tissues.

Offset: A shoot that develops laterally at the base of a plant, often rooting to form a new plant.

Organ: A differentiated part of an organism, adapted for a specific function.

Organelle: A structure within a cell that is specialised for a particular function, e.g., the nucleus and the mitochondria.

Ornithology: The scientific study of birds.

Osculum: The opening in a sponge for expelling water.

Osmoregulation: The maintenance of the correct proportions of water and salts in the body of a living animal

Osmosis: The diffusion of solvent through a semipermeable membrane until there is an equal concentration of solution on either side of the membrane.

Osmotic pressure: The pressure developed across a membrane as a result of osmosis. For a given solution it is the pressure required to prevent osmosis from the solution to a pure solvent, such as water.

Ossification: The natural process of bone formation; The abnormal hardening of soft tissue into a bone-like material.

Osteoarthritis: Degenerative joint disease due to destruction of joint cartilage, cause pain and impaired mobility of affected joint.

Osteocyte: A bone cell.

Oviduct: A tube through which ova leaves an ovary. In mammals it is called the fallopian tube.

Oviparous: Producing eggs that hatch outside the body.

Ovipositor: Tubular structure, consisting of a pair of valves near the rear of the abdomen, with which most insects lay eggs.

Ovisac: An egg-containing capsule, such as a Graafian follicle.

Ovule: Female reproductive structure consisting of integuments, nucellus, embryo sac, which after fertilisation becomes a seed.

Ovum: Unfertilised female reproductive cell ; an egg cell.

Palate: The roof of the mouth in vertebrates which separates the mouth from the nasal cavity.

Paleontology: The study of fossils and the ancient life forms.

Palisade: Upper part of the mesophyll tissue of a leaf which is the seat of photosynthesis. Consists of cylindrical cells.

Palpitation: Irregular, rapid beating of pulsation of heart.

Pancreas: A long, soft, irregularly shaped gland lying near the stomach. It secretes pancreatic juice into the duodenum and contains the islets of Langerhans, which produce insulin.

Papilla: Small nipple-like projection, e.g., protuberance on top of the tongue, at the root of a hair, at the base of a developing tooth.

Pappus: A tuft of bristles, found on seeds of certain plants, such as dandelions and thistle, that aid dispersal.

Paramoecium: Ciliate protozoans of genus *Paramoecium*, usually oval and having an oral groove for feeding.

Parasite: Any organism that grows, feed, and is sheltered on or in a different organism while contributing nothing to the survival of its host.

Parasitology: The scientific study of parasites.

Parenchyma: Tissue composed of soft, unspecialised, thin-walled cells; A loose connective tissue occurring in flatworms.

Parietal bone: Two large, irregularly quadrilateral bones, that together form the sides and top of the skull.

Parkinson's disease: A neurological disease of the later years, characterised by muscular tremor, slowing of movement, partial facial paralysis, weakness, peculiarity of gait and posture.

Parotid gland: Paired salivary glands, located below and in front of each ear.

Parthenocarpy: The production of fruit without fertilisation or seed production.

Pasteur, Louis: French microbiologist. He developed the process of pasteurisation, vaccines for anthrax, rabies and cholera.

Pasteurisation: The process of destroying most diseases-producing microorganism and limiting fermentation in milk, beer, and other liquids by controlled application of heat.

Patella: A flat, triangular bone located at the front of the knee joint. Also called "kneecap".

Pectin: Complex colloidal substances of high molecular weight found in ripe fruits, such as apples.

Pectoral fin: Either of the anterior pair of fins of fishes.

Pectoral girdle: A skeleton structure in vertebrates, attached to and supporting the forelimbs or fins.

Peduncle: The main stalk of inflorescence, or a stalk or stem bearing a solitary flower.

Pellagra: A chronic disease caused by niacin deficiency.

Pelvic fin (ventral fin): Pair of lateral hind fins of fishes.

Pelvic girdle: Skeletal structure by which the hind limbs are supported and joined to the vertebral column.

Pelvis: A basin shaped skeletal structure, composed of the innominate bones on the sides, the pubis in front, and the sacrum and coccyx behind.

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Penicillin: Antibiotic compounds obtained from *Penicillium* moulds, or produced biosynthetically. Used to treat a wide variety of infections.

Pentadactyl: Having five fingers or toes on each hand or foot.

Pentamerous: Having floral whorls in sets of five.

Pepsin: A digestive enzyme found in gastric juice that catalyses the breakdown of protein to peptide.

Pepsinogen: An inert secretion of the gastric mucosa, converted to pepsin during digestion by the action of hydrochloric acid.

Peptidase: Enzyme, hydrolyses peptides to amino acids.

Perennial: Having a life span of more than two years.

Perianth: Consists of fused calyx and corolla, or, of either of these if the other is absent.

Pericardium: The membranous sac enclosing the heart.

Pericarp: Casing of seeds developed from ovary wall.

Pericycle: The outer most layer of the stele of a plant, usually though not always consisting of a layer of cell.

Periderm: An outer layer of tissue of plant root and stems, consisting of the bark and the layer of growing tissue beneath the bark.

Perigynous (half-inferior): Floral whorls around the edge of a flat or cuplike receptacle containing the ovary.

Periodontal: Tissue surrounding and supporting the teeth.

Peristalsis: Involuntary wavelike muscular contractions that propel contained matter along tubular organs.

Peristalsis: Involuntary wavelike muscular contractions that propel contained matter along tubular organs, as in the alimentary canal.

Peritoneum: The membrane lining the walls of the abdominal cavity and covering the viscera.

Pernicious anaemia: A severe anaemia associated with failure to absorb vitamin B12.

Perspiration: The salty moisture excreted through the pores of the skin by the sweat glands; sweat.

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Pesticide: Chemical used to kill pests, e.g., insects and rodents.

Petal: A separate, often brightly coloured segment of a corolla.

Petaloid: Resembling a petal; petal-like.

Petiolate: Having a petiole.

Petiole: The stalk by which a leaf is attached to a stem; a leafstalk.

Phagocyte (white blood cell): Cell such as a leucocyte that engulf and digest cells, microorganisms, or other foreign bodies.

Phagocyte: A cell such as a leucocyte that engulf and digests cells, microorganisms, or other foreign bodies.

Phagocytosis: The envelopment and digestion of bacteria or other foreign bodies by phagocytes.

Phalanges: The bones of fingers or toes.

Pharyngitis: Inflammation of pharynx.

Pharynx: The section of digestive tract that extends from the nasal cavities and mouth to the oesophagus.

Phloem: The nutrient-conducting tissue of vascular plants, consisting of sieve tubes, companion cell and phloem parenchyma.

Photosynthesis: The physiological process by which chlorophyll-containing cells in plants convert incident light to chemical energy and prepare food in the form of carbohydrates from carbon dioxide and water, with the simultaneous release of oxygen as bye-product.

Phototropism: Growth or movement of a plant part in response to a source of light.

Phyllotaxy: Arrangement of leaves on a stem.

Phylum: A taxonomic division, directly above a class in size.

Physiology: Science of essential and characteristic life processes.

Pith: Soft, spongelike substance in the centre of stems and branches of most vascular plants; White fibrous tissue between the rind and the pulp in fruits like oranges and grapefruit.

Placenta: Part of the ovary to which the ovules are attached.

Placentation: Manner in which placenta is arranged in the ovary.

Plant kingdom: One of the main divisions of the living world.

Plant: Organism with cellulose cell walls, grows by synthesizing inorganic substances, lacks the power of locomotion, lacks specialised sensory organs and nervous tissue.

Plasma membrane: The semipermeable membrane that encloses the cytoplasm of the cell.

Plasma: Clear, yellowish fluid portion of blood or lymph in which cells are suspended.

Plasmasol: A state of cytoplasm that is more liquid than plasmagel. Found in the interior of the cell.

Plasmolysis: Shrinkage or contraction of the protoplasm in a plant or bacterial cell, caused by loss of water through osmosis.

Plasmolysis: Shrinkage or contraction of the protoplasm in a plant or bacterial cell, caused by loss of water through osmosis.

Plastid: Specialised cytoplasmic structures in plant cells.

Platelet: An irregular-shaped disc, found in the blood of vertebrates. Promotes coagulation of blood.

Platyhelminth: Parasitic and non-parasitic worms, characteristically having a flattened body, e.g., tapeworm.

Pleura: Membranous sacs, which line one side of the thoracic cavity and envelop the lungs reducing the friction of respiratory movements to a minimum.

Pleurisy: Inflammation of the pleura, characterised by pain in the chest or side that becomes worse on deep breathing or coughing.

Pneumonia: Disease marked by inflammation of the lung, which becomes non-functional due to the presence of pus in the air sacs.

Pollen tube: The slender tube that grows from a grain of pollen down the style of a pollinated plant to the ovule, and conveys male gametes which fertilise the egg cell.

Pollen: Fine powdery material produced by the anthers of flowering plants and by the male cones of conifers, which contains the male gametes and functions as the male element in fertilisation.

Pollinate: To transfer pollen from anther to stigma of flower.

Polyadelphous: Stamens arranged in three or more groups by means of their united stalks or filaments.

Polyp: A coelenterate having a cylindrical body and an oral opening usually surrounded by tentacles, e.g. hydra or coral.

Polypeptide: Peptide containing between 10 and 100 amino acid.

Polypetalous: Having distinctly separate petals.

Portal system: A vein or group of veins that terminates at both ends in a capillary bed, such as hepatic portal system.

Portal vein: A vein that conducts blood from one organ to another organ other than the heart.

Posterior: Caudal end of the body in an animal or the dorsal side in man; Next to, or nearest the main stem or axis.

Premolar: Any of eight bicuspid teeth located in pairs on each side of the upper and lower jaws.

Prickle: A small, sharp point arising from the epidermis of a branch, leaf, or other plant structure, and containing no woody or vascular tissue.

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Proboscis: Slender, tubular feeding and sucking part of insects.

Procambium: A layer of meristematic tissue from which the vascular tissue is formed.

Promycelium: A germ tube produced by certain fungal spores.

Prostrate: Growing along the ground.

Protein: Nitrogenous organic compounds that contain amino acids as their basic structural unit. Occur in all living matter and are essential for the growth and repair of animal tissue.

Proteose: Water-soluble product of partial digestion of protein.

Prothrombin: A plasma protein that is converted into thrombin during blood coagulation.

Protoplasm: A complex, jelly-like colloidal substance constituting the living matter of plant and animal cells.

Protoxylem: The first type of xylem that is formed from the procambium.

Pseudopod: Temporary protrusion of cytoplasm of a cell. Serves as a means of locomotion and of feeding.

Pteridophyte: Non-flowering plant. Reproduces by spores and has vascular tissue e.g., fern.

Pulp: Soft inner structure of tooth. Has nerve and blood vessels.

Pus: A viscous, yellowish-white fluid formed in infected tissue. Consists of leucocytes, cellular debris, liquefied tissue elements.

Pylorus: Opening of the stomach into the duodenum.

Pyruvic acid: A colourless liquid, formed as a fundamental intermediate in protein and carbohydrate metabolism.

Quill (calamus): Hollow, stem-like main shaft of a feather.

Quinine: Alkaloid derived from certain cinchona barks and used to treat malaria, though now largely replaced by less toxic drugs.

Rabies (hydrophobia): Infectious, often fatal viral disease of wolves, cats, and dogs. Transmitted to humans by the bite of infected animals. Characterised by convulsions and aversion to water.

Raceme: Inflorescence in which stalked flowers are arranged singly along a common main axis with the youngest at the top.

Rachis: A main axis or shaft, such as the main stem of an inflorescence, the shaft of a contour feather, or the spinal column.

Radial symmetry: Arrangement of the parts of an organism around a central axis such that a vertical cut through the axis in any plane produces two halves that are mirror image of each other.

Radical: Growing form the root.

Radius: A long, slightly curved bone, the shorter and thicker of the two forearm bones located on the outer side of the ulna.

Raphide: Needle-shaped crystals found in many plant cells.

Ray flower (ray floret): Flat, strap-shaped marginal flowers in the flower head of certain composite plants e.g. sunflower.

Regenerate: To replace by formation of new tissue.

Relaxation: The return to normal length of inactive muscle or muscle fibres following contraction.

Renin: A milk-coagulating enzyme produced by the stomach.

Reproduction: The sexual or asexual process by which organisms generate others of the same kind.

Reptile: Cold-blooded, egg-lying vertebrates having an external covering of scales and breathing by means of lungs.

Resolving power: A measure of the ability of an instrument to resolve optical images.

Respiration: The metabolic process by which an organism assimilates oxygen, oxidises organic substances in the cells, with the release of energy, carbon dioxide and water vapour.

Rh factor: Antigens on the surface of red blood cells of Rh positive blood that induce adverse reactions with blood cells that lack antigens. Also called "rhesus factor".

Rheumatism: Disorders like fibrositis and rheumatoid arthritis, that affect muscles, tendons, joints, or bones and are characterised by painful inflammation of the joints, discomfort and disability.

Rhizoid: A slender, rootlike filament by which mosses, liverworts, and ferns attach to the substratum and absorb nourishment; A rootlike extension of the thallus of a fungus.

Rhizome (root stock): A rootlike, usually horizontal stem growing under or along the ground, and sending out roots from its lower surface, and leaves or shoots from its upper surface.

Rhizopus: Destructive fungi, e.g., the common bread mould.

Rib: Long curved bones extending from the spine towards the breast bone. Forms a cage which encloses the heart and lungs; Main veins of a leaf.

Riboflavin (vitamin B2): Part of vitamin B complex. Found in milk, leafy vegetables, fresh meat, egg yolks.

Ribosome: Sites of protein synthesis in the cell.

Ringworm: Skin diseases caused by several related fungi Characterised by ring shaped, scaly raised patches on the skin.

RNA: Ribonucleic acid. Has an essential role in protein synthesis.

Root cap: A thimble-shaped mass of cells that covers and protects the tip of a growing root.

Root hair: A thin hair-like outgrowth of a plant root that absorbs water and minerals from the soil.

Root: Usually underground part of a plant that serves as support, and draws water and mineral ions from the surrounding soil.

Rootlet: A small root or division of a root.

Rosette: A circular cluster of leaves or other plant parts.

Roughage (dietary fibre): Coarse, indigestible parts of certain food and fodder that contain cellulose and stimulate peristalsis.

Rubella: A disease, German measles; **Rubeola:** measles.

Rudimentary: Imperfectly or incompletely developed; vestigial.

Runner: A slender, creeping stem that puts forth roots and shoots either from nodes along its length or at the tip.

Saccharide: Compounds of carbon, hydrogen, and oxygen in which the atoms of the latter two elements are in the ratio of 2:1.

Sacroplasm: The cytoplasm of striated muscle fibres.

Sacrum: Triangular bone forming the posterior section of pelvis.

Sagittate: Having the shape of an arrowhead e.g. leaves, anthers.

Scapula(shoulder blade): Large, flat, triangular bones forming the back part of the shoulder.

Scarlet fever: Contagious disease characterised by a scarlet skin rash and high fever.

Scion: Twig containing bud from a woody plant used in grafting.

Sclereid: Cells that make up the sclerenchyma.

Sclerenchyma: Supportive or protective plant tissue consisting of thick-walled, usually lignified cells.

Sclerosis: Hardening of a body part, as of an artery or the spinal cord, especially from tissue outgrowth or disease.

Scurvy: Disease caused by deficiency of vitamin C, characterised by spongy and bleeding gums and extreme weakness.

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Scutellum: Shield-shaped structure, e.g., cotyledon of a grass, scaly plate on the thorax of some insects.

Seed coat: The outer protective covering of a seed; the testa.

Segment: A clearly differentiated, repeated subdivision of an organism or part.

Self-pollination: Transfer of pollen from the anther to stigma of the same flower.

Semi-permeable: Natural or artificial membrane that is permeable to some molecules in a mixture or solution but not to all.

Sensitive plant: *Mimosa pudica,* a plant having leaflets and stems that fold and droop when touched.

Sepal: Usually green segment forming the calyx of the flower.

Sepaloid: Resembling or characteristic of flower.

Septicaemia ("blood poisoning"): A systemic disease caused by pathogenic organisms or their toxins in the bloodstream.

Septum: A thin partition. In filamentous organisms, a cell wall at right angles to the length of the filament.

Serum: Liquid portion of blood plasma from which fibrinogen has been removed; Fluid from the tissues of immunised animals, used especially as an antitoxin.

Sexual reproduction: Reproduction involving union of male and female gametes.

Shaft: Rib of a feather; Section of a hair projecting from the surface of the body.

Sheath: Enveloping structure, e.g., leaf base surrounding a stem.

Sickle cell anaemia: A hereditary anaemia mainly affecting black people, characterised by presence of oxygen-deficient sickle-shaped red blood cells.

Simple microscope: A microscope having one lens or lens system, such as a magnifying glass or hand lens.

Skeleton: Internal vertebrate structure composed of bone and cartilage that protects and supports the soft organs and tissues.

Skin: External, protective covering of the body of vertebrates.

Slow virus: Any infectious virus that has a long incubation period in the body before symptoms of disease appear.

Small intestine: Part of intestine extending from pylorus to caecum. Consists of the duodenum, the jejunum, and the ileum.

Small pox: An infectious viral disease, now eradicated.

Smooth muscle: Unstriated involuntary muscle of internal organs, as of the intestine, bladder, blood vessels, (heart excluded).

Smut: Fungal plant diseases, particularly affecting cereals.

Sperm: A male gamete or reproductive cell, a spermatozoon.

Spermatophyte: Seed bearing plants.

Sphincter: A ring-like muscle that normally maintains constriction of a bodily passage or orifice and that relaxes as required by normal physiological functioning.

Spicule: Tiny needle-like structure of silicate or calcium carbonate supporting the soft tissue of certain invertebrates, e.g., sponges.

Spike: Elongated, racemose inflorescence with stalkless or nearly stalkless flowers arranged along an axis.

Spinal canal: The canal formed by the successive openings in the vertebrae through which the spinal cord and its membranes pass.

Spinal column (spine): Series of articulated vertebrae extending from the base of skull to the base of trunk, encasing the spinal cord and forming the supporting axis of the body; the backbone.

Spirillum: Flagellated aerobic bacteria.

Sporangium: An asexual spore bearing structure in Cryptogams.

Spore: An asexual, usually single-celled reproductive organ characteristic of non-flowering plants.

Sputum: Saliva, mucus from the respiratory tract, and foreign material, coughed up and spat out.

Squamous: Epithelium consisting of flat, scale-like cells.

Stamen: The pollen-producing reproductive organ of a flower.

Staminate: Bearing stamens but lacking pistils.

Staminode: A sterile functionless stamen.

Starch: A carbohydrate, found chiefly in the seeds, fruits, tubers, roots, and stem pith of plants.

Stele: The central core of vascular tissue in a plant stem or root.

Stem: Ascending axis of plant. Bears leaves, flowers and buds.

Sterile: Incapable of reproducing sexually; barren; infertile.

Sterilisation: The procedure of making infertile.

Sternum (breast bone): A long flat bone forming the mid-ventral support of most of the ribs in tetrapod vertebrates.

Stigma: The apex of the pistil of flower, upon which pollen is deposited at pollination.

Stimulus: An agent, action, or condition that elicits or accelerates a physiological or psychological activity.

Stipulate: Leaves having stipules.

Stipule: Small, paired leaf-like appendage at the base of a leaf.

Stock: A plant or stem onto which a graft is made.

Stolon: A stem growing along the ground and taking root at the nodes to form new plants.

Stoma: Minute pores in the epidermis of a leaf or young stem, through which gases and water vapour enter and leave the plant.

Stomach: Enlarged, sac-like part of the alimentary canal, located in vertebrates between the oesophagus and the small intestine.

Streptococcus: Bacteria , occurring in pairs or chains.

Streptomycin: An antibiotic produced from the bacterium *Streptomyces griseus*. Used in the treatment of tuberculosis.

Striated muscle (skeletal muscle): Consisting of elongated, transversely striated fibres, operating under voluntary control.

Stroma: Dense material around the grana in chloroplast.

Style: Any slender, tubular, or bristle like process.

Sub-maxillary: Relating to the lower jaw or the region adjacent to it; submandibular.

Sub-phylum: Taxonomic category between a phylum and a class.

Substrate: Surface on which an organism grows or is attached.

Sucker: A secondary shoot arising from the base of a tree trunk or from the lower part of some shrubs. Gives rise to a new plant.

Sucrose: Disaccharide carbohydrate found in many plants.

Suture: A seamlike joint or line of articulation, such as the line of dehiscence in a seed or fruit.

Sweat gland: Tubular, sweat-producing gland in the skin.

Swim bladder: An organ in fishes, the air bladder.

Tactile: Perceptible to the sense of touch.

Tadpole: The aquatic larval stage of a frog or toad having a tail and gills.

Taeniasis: Infestation with tapeworm.

Tail: The posterior part of animal extending beyond the trunk.

Tapeworm: Long, ribbon-like segmented flatworm, parasitic in the intestines of vertebrates including humans.

Taxonomy: Theory, principles, and process of classifying organisms in established categories according to observed similarities.

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Tegument: An outer covering; an integument.

Temporal bone: Bones forming the sides and base of the skull.

Tendon: Fibrous tissue that connects a muscle to bone.

Tendril: A long, slender, coiling extension, serving as an organ of attachment for certain climbing plants, e.g. grape.

Tentacle: Elongated, flexible protrusion, with ability to grasp.

Tepal: A division of the perianth of a flower.

Tergum: Dorsal body segment of an insect or other arthropod.

Testa: The often thick or hard outer coat of a seed.

Tetanus: Often fatal infectious disease caused by a bacillus.

Thalamus: Receptacle of a flower; Ovoid masses of grey matter that relay sensory stimuli to the cerebral cortex of the brain.

Thalophyte: Plant body undifferentiated into root, stem and leaf.

Thiamine (vitamin B1): A B-complex vitamin.

Thorax: Part of human body between the neck and the diaphragm; The second region of the body of arthropods.

Thorn: Branch modified in the form of a sharp, woody structure.

Throat: Part of the digestive tract between the rear of the mouth and oesophagus and includes the pharynx.

Thromboplastin: A protein complex essential for thrombin formation and blood clotting. Also called "thrombokinase".

Thymus: A ductless gland like structure, situated just behind the top of the breastbone, that during early childhood plays some part in building resistance to disease by producing lymphocytes but in adults is usually vestigial.

Thyroid gland: A two-lobed endocrine gland found in all vertebrates, located in front of and on either side of the trachea in humans, and producing the hormone thyroxine.

Thyroxine: An iodine containing hormone.

Tissue: Group of cells performing a specific function.

Tocopherol: Vitamin E. Deficiency leads to sterility in rodents.

Tongue: Fleshy muscular organ, attached in most vertebrates to the floor of the mouth. It is the principle organ of taste, and moves to aid chewing and swallowing.

Tonsil: A mass of lymphoid tissue, embedded in the lateral walls of the aperture between the mouth and the pharynx.

Tonsillitis: Tonsil inflammation.

Tooth: Hard, bone-like structure rooted in sockets in the jaw, used to seize, hold, or masticate food.

Toxaemia: Blood poisoning.

Toxic: Harmful, destructive, or deadly; poisonous.

Toxin: A poisonous substance, secreted by certain organisms and capable of causing toxicosis when introduced into the body

Trachea: Internal respiratory tubes of insects and some other terrestrial arthropods.

Tracheid: Elongated, tapering, supporting and conductive cells in woody tissue.

Triceps: Three headed muscle, e.g., the large muscle running along the back of the upper arm.

Tricuspid: Having three points or cusps, e.g., a molar tooth.

Tropism: The directional growth movement of a plant part in response to an external stimulus.

Tsetse fly: Bloodsucking African flies transmitting pathogenic trypanosomes to human beings and livestock.

Tubefoot: External, fluid-filled muscular tubes of echinoderms, such as the starfish, serving primarily as organs of locomotion.

Tuber: A swollen, usually underground stem or root.

Tuberculosis: An infectious disease manifesting itself in lesions of the lung, bone, and other parts of the body.

Tumour: A noninflammatory abnormal growth arising from existing tissue but growing independently and serving no physiological function.

Tympanum: The tympanic membrane; the ear drum.

Typhoid: An acute, highly infectious disease caused by the typhoid bacillus, *Salmonella typhi,* transmitted by contaminated food or water and characterised by red rashes, high fever, and in severe cases, intestinal haemorrhage

Typhus: Infectious disease caused by microorganisms of the genus *Rickettsia,* characterised by severe headache, sustained high fever, depression, delirium, and widespread rashes.

Umbel: Flat-topped flower cluster. The individual flower stalk arise from about the same point, e.g., carrot.

Ungulate: Having hoofs.

Unicellular: Consisting of one cell.

Urea: An excretion product of protein metabolism in mammalian urine and other body fluids.

Ureter: The long, narrow duct that conveys urine from the kidney to the urinary bladder.

Urethra: The canal through which urine is discharged in most mammals and which serves as the male genital duct.

Uric acid: A white crystalline compound, the end product of purine metabolism in man and other primates, birds, terrestrial reptiles, and most insects.

Urinary bladder: Muscular membrane-lined sac situated in the anterior part of the pelvic cavity and used as a urine reservoir prior to excretion.

Urine: The fluid and dissolved substances, including urea, secreted by kidneys, stored in the bladder, and excreted from the body through the urethra.

Uriniferous: Conveying urine.

Urogenital: Involving both, the urinary and genital functions.

Urology: The medical study of physiology and pathology of the urogenital tract.

Vaccination: Inoculation with vaccine in order to protect against a given disease.

Vaccine: A suspension of weakened or killed disease-causing microorganisms, incapable of inducing severe infection but capable, when inoculated, of stimulating the production of antibodies against the virulent microorganism.

Vacuole: Small cavity in the cytoplasm of a cell, that contains air, water, sap, partially digested food or other materials.

Valve: A membranous structure in a hollow organ or passage, as in artery or vein, that retards or prevents the return flow of bodily fluid.

Vascular bundle: A strand of supportive and conductive plant tissue consisting essentially of xylem and phloem.

Vascular plant: Includes ferns and seed-bearing plants characterised by a system of specialised conductive tissue.

Vascular tissue: Plant tissue consisting of vascular bundles.

Vascular: Characterised by, or containing vessels for the transmission or circulation of plant, animal fluids such as blood, lymph, or sap.

Vasoconstriction: Constriction of a blood vessel.

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Vasodilation: Dilation of a blood vessel.

Vector: An organism that carries pathogens from one host to another.

Vegetable: A plant cultivated for edible part or parts.

Vegetative: Pertaining to asexual reproduction, such as fission or budding.

Vein: A vessel that transports blood towards the heart ; Vascular bundles that form the branching framework and support of leaf.

Vena cava: Either of the two large veins in air-breathing vertebrates that enter and return blood to the atrium of the heart.

Venation: Arrangement of veins in a leaf or insect's wing.

Venereal disease: Any of several contagious diseases, such as syphilis and gonorrhoea, contracted through sexual intercourse.

Venom: A poisonous secretion of some animals, such as certain snakes, spiders, scorpions, or insects, usually transmitted by a bite or sting.

Ventricle: The chamber on the left side of the heart that receives arterial blood from the left atrium and contracts to drive it into the aorta.; The chamber on the right side of the heart that receives venous blood from the vena cava and drives it via the right atrium into the pulmonary artery.

Venule: A minute vein, such as one joining with a capillary or branching from a vein in an insect wing.

Vermiform appendix: The wormlike, closed, projection of the caecum found in certain mammals. Vestigial in humans.

Vertebra: Bones or cartilaginous segments forming the spinal column.

Vesicle: A small bladder-like vacuole, cell, or cavity.

Vestigial: Occurring or persisting as a rudimentary structure.

Villus: Any minute projection arising from a mucous membrane.

Virology: The study of viruses and viral diseases.

Virus: Submicroscopic pathogens consisting essentially of a core of a single nucleic acid surrounded by a protein coat, having the ability to replicate only inside a living cell.

Vital capacity: The maximum amount of air that can be expelled from the lungs after breathing in as deeply as possible.

Vitamin: Complex organic substances occurring naturally in plant and some animal tissue, and essential in small amounts for the control of metabolic processes.

Viviparous: Giving birth to living offspring that develop within the mother's body. Said of most mammals.

Vocal cords: Bands or folds in the larynx that vibrate when pulled together and when air passes over them from lungs, thereby producing vocal sounds.

Vomit: To eject contents of the stomach through the mouth, usually in a series of involuntary spasmodic movements.

Whip graft: A horticulture graft in which a tongue cut on the sloping base of the scion is inserted into a slit made on the sloping top of the stock.

Whooping cough (pertussis): An infectious disease caused by the bacterium *Haemophilus pertussis*, involving catarrh of the respiratory passage and characterised by spasms of coughing interspersed with deep, noisy inspiration.

Whorl: An arrangement of three or more parts, such as leaves or petals, radiating from a single organ or node.

Wilt: To become limps or flaccid; droop.

Wing: Feather-covered modified forelimb of a bird ; Veined membranous structure extending from the thorax of an insect; Thin membranous extension, as of the fruit of the sycamore or ash.

Worm: Invertebrates, such as those of phyla Annelid, Nematoda, or Platyhelminthes, having a long, flexible rounded or flattened body, often without obvious appendages.

Xerophyte: A plant, such as a cactus, that grows in deserts and is adapted to an environment deficient in moisture.

Xylem: The supporting and water conducting tissue of vascular plants.

Yeast: Unicellular fungi, reproduces by budding and capable of fermenting carbohydrates.

Yellow fever: An acute infectious disease of subtropical and tropical areas, caused by virus transmitted by a mosquito of the genus *Aedes* and characterised by jaundice and dark-coloured vomit resulting from haemorrhages.

Yolk: The nutritive material of an animal ovum, consisting primarily of protein and fat; especially, the yellow, usually spheroidal mass of the egg of a bird or reptile.

Zoology: The biological study of animals.

Zygomorphic: Bilaterally symmetrical. Capable of being symmetrically divided only along a single longitudinal plane.

Zygospore: A thick-walled spore formed from the zygote.

Zygote: The cell formed by the union of two gametes.

Zymase: Enzyme complex, first isolated from yeast, that converts hexose sugar to ethanol and carbon dioxide.

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